DEPARTMENT OF COMMERCE
BUREAU OF FISHERIES
HENRY O'MALLEY, Commissioner

ARTIFICIAL PROPAGATION OF WHITEFISH, GRAYLING, AND LAKE TROUT

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APPENDIX III TO THE REPORT OF THE U. S. COMMISSIONER OF FISHERIES FOR 1923

Bureau of Fisheries Document No. 949

PRICE, 15 CENTS
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Washington, D. C.

WASHINGTON
GOVERNMENT PRINTING OFFICE
1923

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THE WHITEFISH.

RANGE.

The common whitefish (*Coregonus clupeaformis*) is eminently a lake fish. It exists throughout the Great Lakes region and is especially abundant in Lakes Erie, Huron, Michigan, and Superior. The eastern limit of its range is Lake Champlain, and it is found in Lake Winnipeg, and possibly farther west. It is landlocked in Otsego Lake, N. Y. Efforts to introduce it into new waters in the States of the Pacific coast have not been successful. It has been established in Flathead Lake, Mont., Lake Coeur d'Alene, Idaho, and possibly other waters in the Rocky Mountains.

DESCRIPTION.

The body of the common whitefish is rather long and compressed, and the back, especially in adults, is arched in front; the greatest depth is about one-fourth the body length. The head is small and

[1] Appendix III to the Report of the U. S. Commissioner of Fisheries for 1923. B. F. Doc. No. 949. This document represents a revision and enlargement of the chapters on "The Whitefish," "The Graylings," and "The Lake or Mackinaw Trout" from A Manual of Fish-Culture, Based on the Methods of the United States Commission of Fish and Fisheries, with Chapters on the Cultivation of Oysters and Frogs, revised edition, published in 1900.

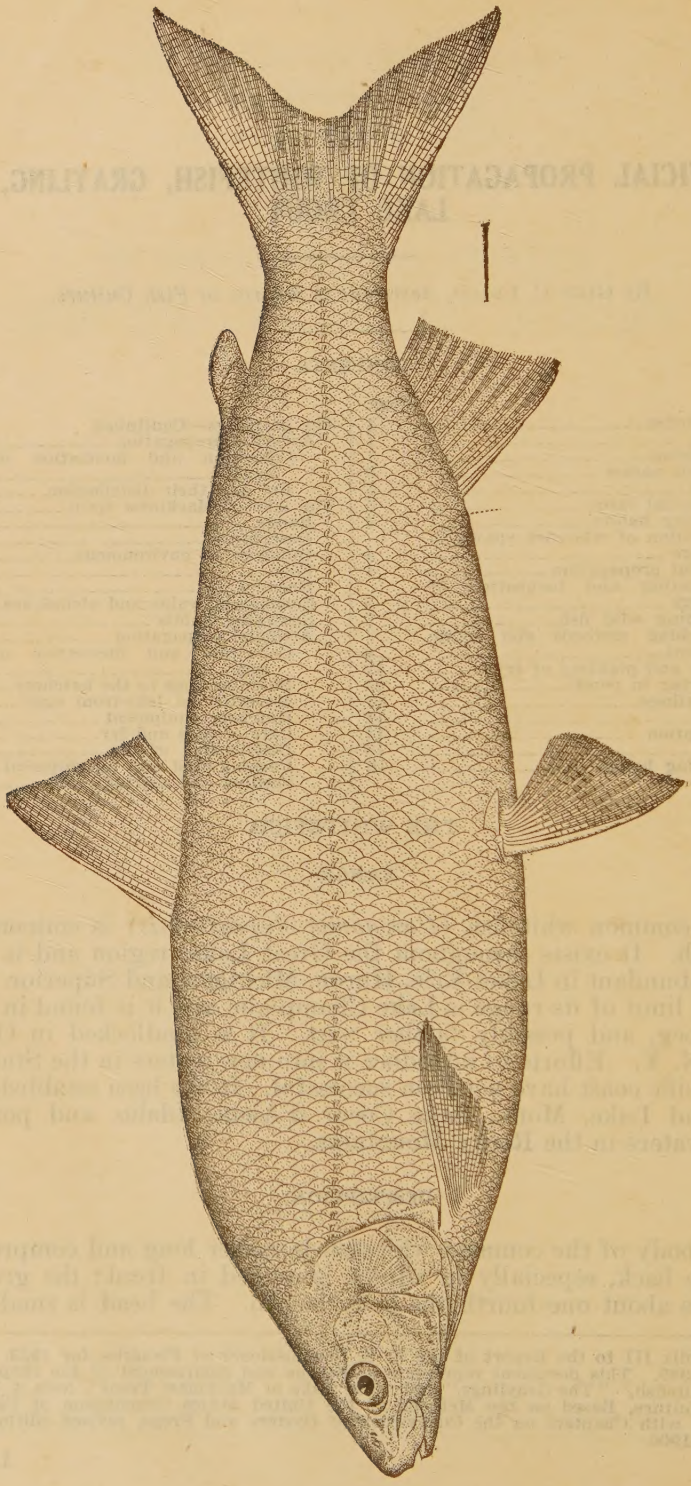

FIG. 1.—Common whitefish, *Coregonus clupeaformis*.

short, contained about five times in the length of the body; the snout is blunt; the mouth is small and nearly horizontal with the lower jaw included; the maxillary is short and broad, reaching to a point near the pupil; the mandible extends to a point under the posterior edge of the eye. The eye is small, its diameter being about one-fifth the length of the head. The rays in both the dorsal and anal fins number 11. The number of rows of scales along the side of the body varies from about 82 to 92, with about 11 above the lateral line and 8 below. The gill rakers number about 28, of which 10 are on the upper arm of the gill arch; the longest are contained about twice in the length of the eye. The general color of this fish is a satiny white, with a faint olive-green shade on the back. The fins are uniformly white, except the caudal, which normally has a dark edge.

COMMON NAMES.

This fish has a number of common names in different parts of its range. It is the whitefish par excellence of the United States and Canada. As found in Otsego Lake, N. Y., it is inappropriately called "Otsego bass." In allusion to its humped back it is called "high-back whitefish," "bowback whitefish," "buffalo-back whitefish," and other similar names in Lake Superior.

HABITS.

Although more is known of the habits of this species than of any other member of the group, many phases of its life are still obscure, as it remains in deep water most of the time. Besides the regular annual movements of the schools to the spawning grounds there are other well-marked migrations in some lakes. Whether these depend on food, temperature, enemies, or other causes is not known. Owing to its small, weak mouth, it is seldom taken with a baited hook. It subsists on minute animal food, chiefly crustaceans, mollusks, and insect larvæ. The food of the fry and young fish is almost wholly small crustaceans.

COMMERCIAL VALUE.

The whitefishes are by far the most important group of freshwater fishes of North America, probably of the world. The common whitefish is the best of the tribe, but some of the others nearly equal it in merit, and all are more or less esteemed as food. The common whitefish reaches a larger size than any other species of whitefish in the United States. Examples weighing over 20 pounds have been taken, but the average weight is under 4 pounds. Among the fishes of the Great Lakes the common whitefish ranks next in value to the ciscoes and the lake trout. In 1917 the catch in the United States amounted to about 6,288,000 pounds, having a value of $731,519. If to this is added the yield of ciscoes and other species of whitefish, the aggregate is over 54,000,000 pounds, having a value of nearly $2,600,000. The market value of the whitefishes taken in 1920 in the British Provinces was reported as $1,315,932, a sum representing about 20,356,000 pounds.

Whitefish fishing is done chiefly with gill nets set at or near the bottom in comparatively deep water, although considerable quanti-

ties of whitefish are also taken in pound nets, trap nets, and seines. A very large part of the catch reaches the market in a fresh condition, although considerable quantities formerly were salted. The leading centers of the trade are Chicago, Detroit, Sandusky, Cleveland, Erie, and Buffalo, whence the fish are shipped frozen or in ice to all parts of the country.

SPAWNING HABITS.

The spawning season of the whitefish in the western end of Lake Erie begins the early part of November and continues into December. At this season there is a general movement of the fish to shoal parts of the lakes, similar to the migration of anadromous fishes from the ocean to the rivers. Some of the foreign whitefish are typical anadromous species. After spawning the fish return at once to the deeper water.

The spawning habits of whitefish confined in pens have been observed. The fish rise to the surface, occasionally in pairs, and rarely in trios of one female and two males, the female emitting a quantity of spawn at each rise. The males, always the smaller fish, persistently follow the female and discharge milt at the same time the eggs are emitted.

Whitefish reach maturity in the third or fourth year. A full-grown specimen deposits from 10,000 to 75,000 eggs, depending on its size. A rule for determining the approximate spawning capacity is to allow 10,000 to 12,000 eggs for each pound of the fish's weight. The eggs are one-eighth of an inch in diameter and are of an amber color. They swell somewhat after impregnation. The number per quart varies from 36,000 in Lake Ontario to 40,000 in Lake Erie.

DESTRUCTION OF WHITEFISH SPAWN IN NATURE.

In nature the eggs of the whitefish are subjected to the attacks of many enemies for nearly five months. The mud puppy (*Necturus maculatus*), commonly known as "lizard" or "water dog" by the people along the lakes, is especially destructive. During the winter months many of these animals are pumped up with the water supply of the Put in Bay station. The stomachs of a considerable number of them contain whitefish and cisco eggs.

Another voracious destroyer of whitefish eggs is the common yellow perch (*Perca flavescens*). The deck of a boat has been seen covered with the eggs of whitefish and cisco pressed out of the stomachs of perch taken the last of November from gill nets on the reefs, where they had gone to feed on the eggs.

The various smaller Cyprinidæ and some other fishes, crawfish, and wild fowl make the eggs of fishes a considerable portion of their diet, and those eggs that require the longest period in hatching suffer most.

ARTIFICIAL PROPAGATION.

The artificial propagation of whitefish has long since passed the experimental state and has attained a high degree of perfection. The work can be carried on with great facility, and its value is especially apparent when it is considered that under natural conditions only a very small percentage of the eggs hatch, whereas

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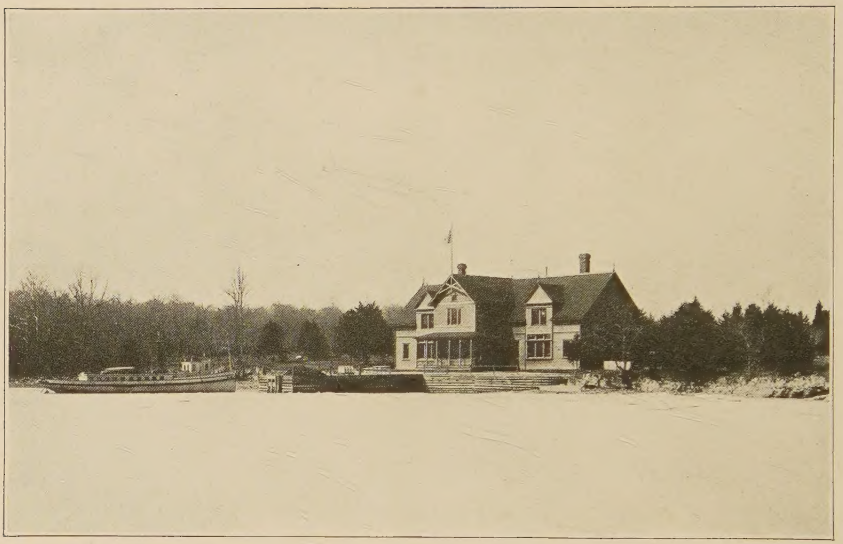


FIG. 2.—Put in Bay (Ohio) hatchery.

FIG. 3.—Collection of whitefish eggs, Put in Bay, Ohio.

through artificial propagation from 75 to 95 per cent are productive. Practically all the eggs taken for hatching purposes are obtained from fish caught by the commercial fishermen and otherwise would be lost or sent to market with the fish.

The methods of culture hereafter referred to are those pursued at the Put in Bay (Ohio) station, but they do not differ in any essential particular from those in general use. In the fiscal year 1921 the Bureau of Fisheries hatched and planted 420,450,000 whitefish fry.

COLLECTION AND INCUBATION OF EGGS.

The taking, impregnating, and handling of whitefish eggs are simple processes, though they require great care at every stage. Eggs are often injured by undue haste in stripping, and many are lost by allowing them to fall too great a distance into the spawning pan. The eggs are very delicate when first taken and before the absorption of water has made the investing membrane tense, and if roughly treated they will be seen to be ruptured as viewed under the microscope. With care about four-fifths of the eggs will hatch. While scarcity of milt may lead to nonfertilization of the eggs, the manner in which the milt is brought in contact with the eggs is a more common cause of failure.

The eggs supplied by each spawn taker should be examined daily. If it is found that a considerable number have ruptured yolks, it may be taken for granted that the spawn taker has handled the fish and eggs roughly, and if many are unimpregnated it is evident that he did not use sufficient milt, or that it was not properly applied to the eggs. Eggs or milt taken from fish that have been dead for any length of time should not be used.

At Put in Bay eggs are obtained from fish captured in pound nets and gill nets, often at considerable distances from the station. The spawn taker, who is employed to take the eggs from the fish as they are lifted from the nets into the boat, has with him two or three 6-quart pans, coated with asphaltum varnish to prevent rusting, in which he takes the spawn, a wooden keg or tin can holding from 10 to 15 gallons, a 10-quart wooden pail, and a tin dipper. He is clothed in waterproof garments, and his left hand is covered with a woolen mitten for convenience in handling the fish.

After several ripe females and some ripe males are collected a female is taken up and the body slime, which would interfere with impregnation if allowed to fall into the pan, is carefully removed. The spawn taker then grasps the fish firmly in his left hand just forward of the tail. The right hand is placed under the fish just back of the pectoral fins, and the fish is held firmly against the body, with the vent 4 or 5 inches from the bottom of the pan. This position of the fish's body brings pressure on the abdomen, facilitates the flow of the eggs through gravity, and prevents them from being injured by falling too far.

On applying a gentle pressure the eggs will flow in a steady liquid stream about a quarter of an inch in diameter, and a considerable portion of them can be ejected before the hand need be moved. As soon as the stream slackens the hand is moved slowly toward the vent, but only sufficiently to keep the eggs flowing steadily. When the stream finally stops, the hand is placed in its former position

and the process repeated until all good eggs have been secured. If, as is frequently the case, a considerable number of white eggs appear when nearly all the ripe eggs have been emitted, the effort should cease.

In the dry process of impregnation, which is now generally conceded to be superior to the wet process of fertilization, the pan in which the eggs are taken is dampened by dipping it in water before stripping begins. After one or two females have been manipulated the milt from one or two males is added to the eggs, this being done by grasping the fish between the thumb and fingers 2 or 3 inches forward of the vent and moving the fingers toward the opening. The milt comes in a stream, an average fish yielding about a teaspoonful. If ripe males are scarce, the fish is laid aside, as a considerable amount of additional milt may be secured from it a few minutes later in case it is needed.

When the pan is one-third to one-half full of spawn and milt, the spawn taker stirs the eggs gently to incorporate them thoroughly with the milt, using for the purpose the tail of a fish from which the slime has been carefully removed. The pan is then partly filled with water and the mass stirred again very gently. After standing two or three minutes the water is poured off and fresh water added, this operation being repeated until the water flows off clear. The eggs are then poured into a keg or can that has previously been filled with water and the mass again stirred very gently. It is necessary to change the water on the eggs at least once an hour, oftener if the weather is warm, and they should be stirred gently to the bottom of the keg every 30 minutes until placed in running water in the hatchery.

After finishing his work the spawn taker delivers the eggs to the man in charge of field operations, who cares for them until the arrival of the collecting steamer, when they are taken on board and transported to the hatchery, some two to five hours having elapsed since they were taken. At the station the eggs are kept in the kegs in which they were placed by the spawn taker, and in the meantime the water is changed once every hour until the next morning, the mass being stirred to the very bottom whenever a change is made. In this way the eggs are hardened with less injury than would result if they were immediately placed in the jars.

Formerly, in shipping eggs from distant field stations, they were kept in running water in kegs, under the care of a watchman, but experience has demonstrated that it is much better to ship them in cases on trays. After being in water from 8 to 10 hours whitefish ova may be safely placed two or three layers deep on trays and shipped to an indefinite distance. If the air temperature is as high as 55 to 60° F., the case must be supplied with ice; if it is below 32° care must be taken to prevent freezing.

The field shipping cases are usually constructed of lumber three-fourths of an inch thick and of sufficient depth to hold 20 trays. The bottom tray and the top tray are not used for eggs. Cleats at the four inner corners hold the trays about 1¼ inches from the sides of the case.

A *tray board* is a convenience in spreading eggs on the trays. This consists of a smooth board some 4 inches greater in length and width than the egg trays, with a raised rim one-half inch high and

water-tight. The tray is placed in the tray board, which has previously been filled with water. The eggs are poured on the partly submerged tray and at once spread evenly over its surface. For longer distances greater precautions must be taken and a packing case that has space for proper insulation and ice used. Several modifications of this type of case are in general use in fish-cultural work.

After the eggs are placed on trays and drained they are covered with a thickness of mosquito netting that has been well washed and left damp. If the eggs are to go by express, unaccompanied by a messenger, directions stating that they must be kept cool but not permitted to freeze are fastened to the case. Whitefish eggs, accompanied by an attendant, have been safely shipped from Northville, Mich., to Australia. Where eggs are to be shipped from one station to another, in care of a messenger, the regular field cases are used.

The trays used at the station are 18 inches square and are made of white pine ¾ by 1 inch, mortised together at the corners, with the widest side of the strip horizontal. Cheesecloth or linen scrim is tacked on the bottoms of these frames with galvanized or copper-coated tacks, the cloth being stretched very taut to prevent its sagging after being wet and dried. The tacks are spaced 2½ to 3 inches apart, so that in a year or two the cloth may be retacked between the spaces to take up the slack. As the trays are square, they fit into the cases either way, thus saving time in packing. Square cases are also more convenient to store and for general handling. One of these trays will hold 100,000 whitefish eggs.

Where the eggs have to be retained in the field for several days they are sometimes kept in floating boxes adapted for the purpose, but unless the conditions are very favorable it is far better to place them on trays, sprinkling them lightly once in two or three days. (See description of floating box on p. 23.)

When taken from the kegs and trays at the hatchery, the eggs are passed through a screen with meshes sufficiently large to permit the passage of a single egg in order to remove scales and other foreign substances that may be present. The screen is floated in a washtub partly filled with water, with the wire netting well submerged.

Wooden kegs are preferred to tin cans for handling eggs and fry, as their contents are not subjected to sudden changes in temperature and can be readily examined, and as the water can be more easily poured off without risking the loss of eggs. Kegs are also much lighter, cost only a sixth as much as cans, and last longer. For shipment in wagons or by rail, however, tin cans made with covers are indispensable. The kegs should be of white pine, made large enough to hold about 15 gallons, and painted on the outside but not inside. They should be provided with iron drop handles.

PENNING WILD FISH.

The uncertainty of climatic conditions and the liability of failure to obtain spawning fish during the severe storms occurring in November make it desirable, whenever practicable, to capture fish when the weather is favorable and place them in pens to ripen. If the fish are driven off their spawning grounds by heavy storms,

they do not return in large numbers during the spawning season, and the only way to insure a satisfactory supply of eggs is to pen the fish. Penning has been abandoned in most of the Great Lakes fields, because most of the fish are taken by gill nets. Since pound nets are seldom used, the green fish can not be obtained. Most of the fishing boats take their own eggs and deliver them to the bureau's agent in charge of the field.

The pens are usually made about 16 feet long, 8 feet wide, and 5 feet deep and are placed end to end in two rows, with a plank walk between as a convenience in caring for them. A partition is placed in the center of each pen, dividing it into two compartments, each 8 feet square. In each compartment is a false bottom held down by two 2 by 4 pieces fastened to the sides. When the fish are to be removed the false bottom is raised and held at any desired height by inserting pins in the 2 by 4 pieces and the sides of the pens. The fish must be handled as little and as gently as possible, otherwise the eggs will form into a hard mass and never ripen. One cause of injury is the scoop net with which they must be handled, the knots and twine being so hard that they injure the delicate scales of the whitefish in their violent struggles when taken from the water.

Although crates or inclosures of wood construction have been very generally used by the Bureau of Fisheries for penning whitefish, retaining inclosures of cotton webbing are proving very satisfactory in Lake Ontario.

HATCHING METHODS AND EQUIPMENT.

The water supply in the hatchery at Put in Bay is obtained through a pipe extending 75 to 100 feet into Lake Erie, the water being elevated by pumps to supply tanks in the loft of the hatchery, whence it is distributed by the usual methods of piping. Two circular galvanized-iron supply tanks are used, each having a capacity of approximately 18,000 gallons. These tanks are necessary in order to give equal pressure in the pipes and to provide an even supply of water to the whitefish batteries. In the event of being obliged to suspend pumping operations for a short time, there will be sufficient water in the supply tanks to care for the eggs for a period of several hours. A float connected with the throttle valve of the pumps is so arranged in the tanks as to maintain a steady water level therein.

Whitefish eggs are hatched in the open-top McDonald, Downing, and Chase jars, the Downing and Chase jars being more generally used. On arrival at the hatchery the eggs are taken from the shipping-box trays and placed in tubs of water to harden. After remaining in the tubs from 12 to 14 hours, during which time the water is changed once an hour, the tub of eggs is placed on a movable stand and the eggs measured into jars by means of a dipper. The jar is first filled with water and a shallow funnel with an outlet extending well into the jar inserted, so that the water will stand as high in the funnel throat as possible. In this way the eggs are not subjected to a fall from the dipper to the jar.

From this stand the jars are passed to a man who sets them up on the battery. Tin tubes are placed in the jars and connected with faucets supplying the water by rubber tubes. In the battery described each jar on the top row is provided with a water supply of

FIG. 4.—Pens used in holding whitefish, Put in Bay, Ohio.

FIG. 5.—Interior of Put in Bay (Ohio) hatchery showing whitefish troughs and battery.

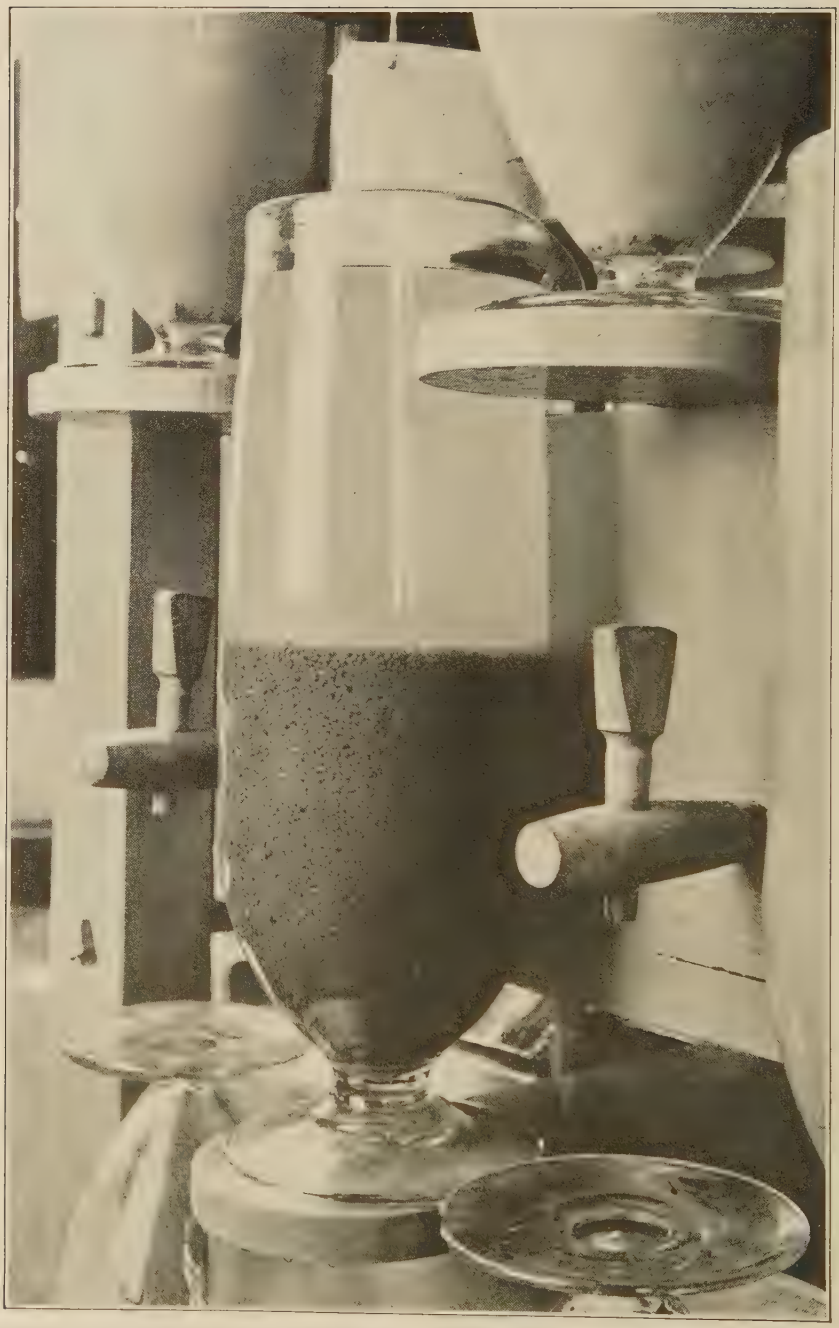


FIG. 6.—Close-up of open-top Downing hatching jar.

FIG. 7.—Unfertilized whitefish egg 24 hours old.

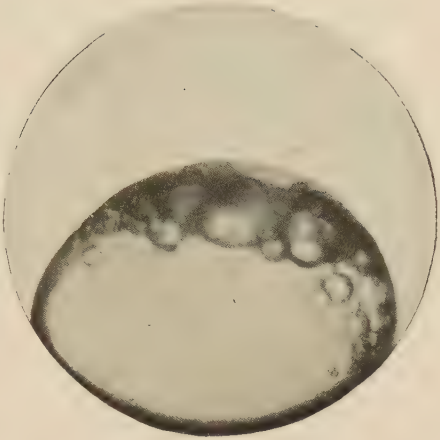


FIG. 8.—Fertilized whitefish egg 6 hours old, germinal disks forming, no segmentation having taken place.

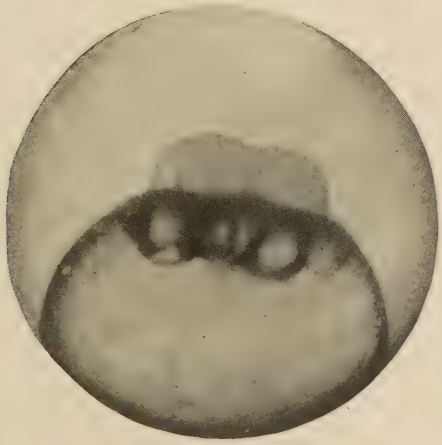


FIG. 9.—Whitefish egg, 12 hours, showing first cleavage, water 38°.

FIG. 10.—Whitefish egg, eighteenth hour, water 38°, showing second segmentation, four cells formed.

FIG. 11.—Whitefish egg, 24 hours, water 38°.

FIG. 12.—Whitefish egg, 48 hours, water 38°.

DEVELOPMENT OF THE WHITEFISH EMBRYO.

FIG. 13.—Fertilized whitefish egg, 72 hours old, showing segmentation well advanced.

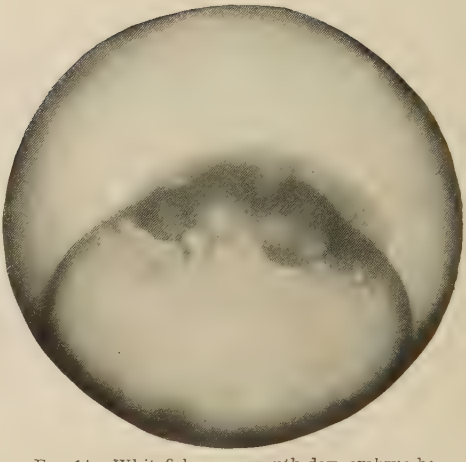


FIG. 14.—Whitefish egg, seventh day, embryo beginning to show.

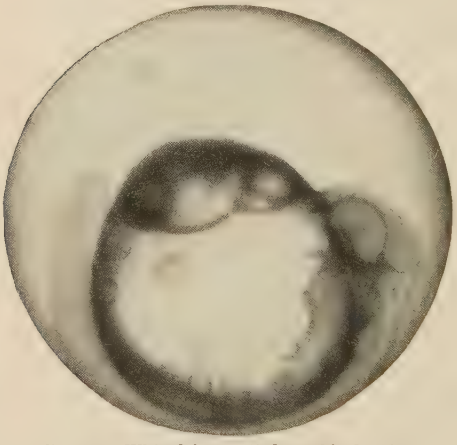


FIG. 15.—Whitefish egg, 43 days old, showing embryo.

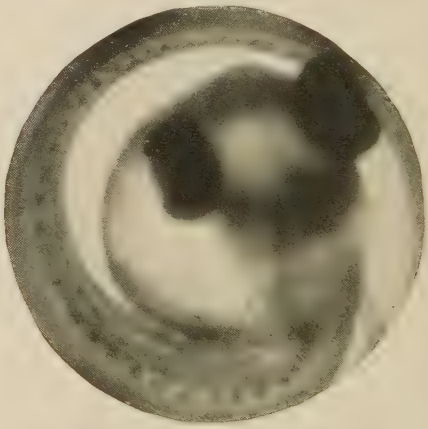


FIG. 16.—Whitefish egg, 90 days old, showing embryo.

FIG. 17.—Whitefish egg, yolk sac ruptured by rough handling, 24 hours old.

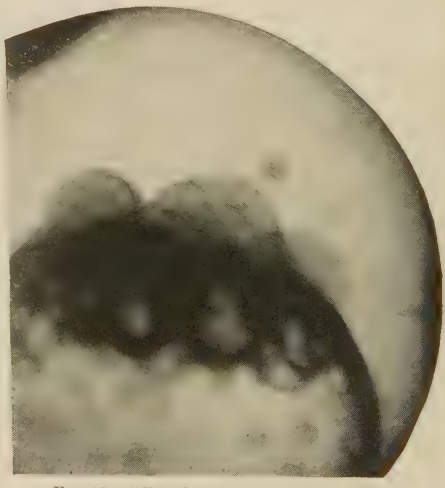


FIG. 18.—Whitefish egg with triple disks.

DEVELOPMENT OF THE WHITEFISH EMBRYO.

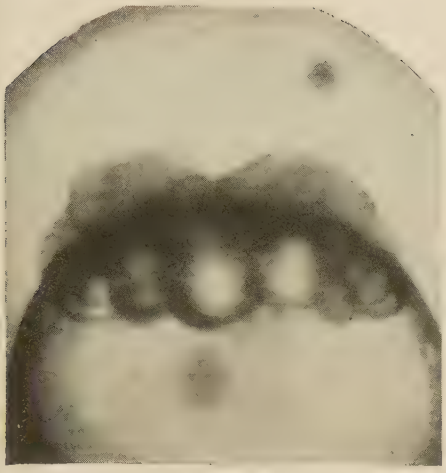


FIG. 19.—Whitefish egg, showing twin disks, 3 days old.

FIG. 20.—Whitefish egg, showing twin disks, 6 days old.

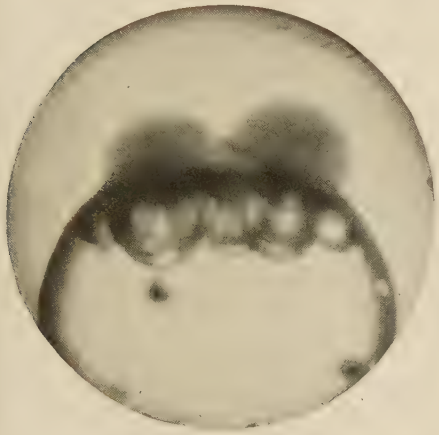


FIG. 21.—Whitefish egg, showing twin disks, 7 days old.

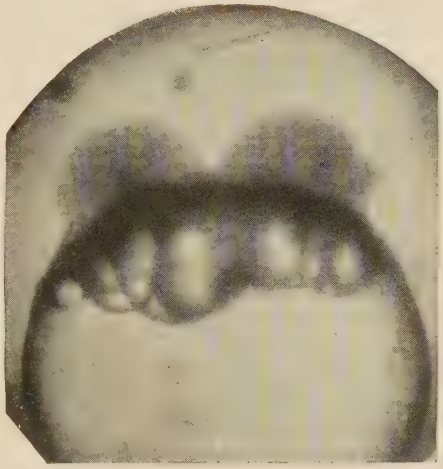


FIG. 22.—Whitefish egg, showing twin disks, 8 days old.

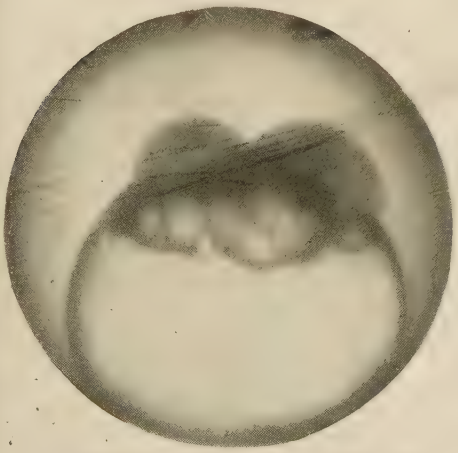


FIG. 23.—Whitefish egg, showing twin disks, 13 days old.

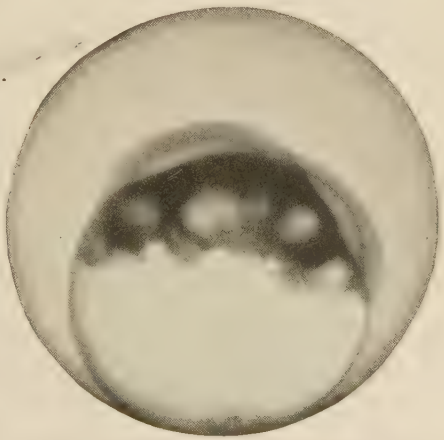


FIG. 24.—Whitefish egg, showing twin disks, 15 days old.

FIG. 25.—Double-headed whitefish fry, just hatched.

FIG. 26.—Double-headed whitefish fry.

FIG. 27.—Curved spine, a common deformity of whitefish fry.

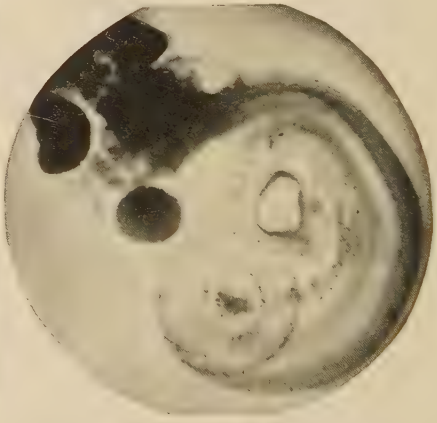


FIG. 28.—Whitefish fry just hatched, three-eyed, curved spine.

FIG. 29.—A common deformity of whitefish fry.

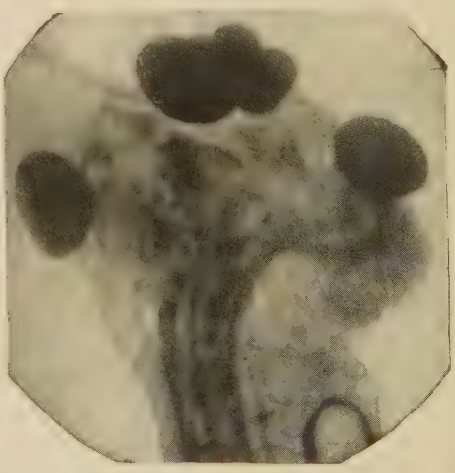


FIG. 30.—Four-eyed whitefish fry.

approximately 5 quarts per minute at the beginning of incubation, which amount is reduced to 4 quarts later on. This water supplies in turn the succeeding rows of jars in the battery. For this reason the jars on the upper row should never be removed without making provision to supply those below.

In a mean water temperature of 35° F. the eye spots of the fish are visible to the unaided eye in about 40 days, and the entire incubation period averages 133 days. The food sac is absorbed in from 5 to 10 days after the fry have hatched, the time varying somewhat with the period of incubation.

The microscope is a great aid in whitefish culture, enabling the operator to determine the exact percentage of dead eggs and, to a great extent, the cause of their loss, allowing him to remedy some if not all of the evils. For examining eggs in their early stages the microscope is placed horizontally, the eggs being held in a cell filled with water. This may be made easily by fastening two ordinary glass slides to a strip of wood one-eighth of an inch thick, with a portion cut away to form a receptacle for the eggs. The wood is thoroughly saturated with asphaltum varnish, and after drying the sides should receive a thin coat, the sides being laid on and placed under pressure to dry. When dry, an additional coat to the outer joints of contact will guard against possible leaks. Such cells are not satisfactory and a good examination of the eggs can not be made with them. Most optical houses are able to supply what is known as "watch crystals" that are made especially for this purpose.

If the egg be examined six to eight hours after being fertilized, the germinal disk will be found to have contracted to a saucer-shaped cap, extending over about one-fifth the surface of the yolk. It is smooth and even, gradually thinning to a sharp outer rim, with a thickness of about one-fifth its diameter in the center of the cap. Segmentation not having commenced at this stage, the impregnated eggs can not be distinguished from the unimpregnated ones. At 18 hours segmentation will be well advanced and the disk will have contracted into six or eight rounded nodules of uneven size, with well defined valleys between, the sharp rim having disappeared. At 24 hours, which is the best time to determine the percentage of live eggs, the disk will present a somewhat similar appearance except that it will be divided into 25 or more segments, easily seen under the glass. The disk of the unimpregnated egg of the same age forms an almost exact hemisphere, is perfectly smooth in appearance, and is therefore easily distinguishable from a live egg. Segmentation now proceeds rapidly, and at 72 hours the cell looks about the size of a mustard seed under a 1-inch objective, the most suitable power to use in this work.

During the entire period of incubation, but more especially in its early stages, the eggs should be worked as gently as possible, only enough water being used to give them sufficient motion to prevent "banking." Just at the commencement of incubation they require about 5 quarts of water to the jar per minute, but later they can be run with a quart less per minute. For the first week or more the eggs require constant watching, and although the whitefish egg is not considered adhesive, agglutination will ocasionally occur when the water becomes roily, and unless the banks thus formed are separated by gentle stirring with a feather (the long feathers of a turkey wing are

suitable) the eggs forming the pack will soon die and form a mass in the jar.

In a few days, varying with the water temperature, the unimpregnated and other dead eggs begin to fungus; that is, a fungous growth develops upon them and they rise to the top of the egg mass. Such eggs must be removed with a siphon immediately, and if live ones are among them they should be set up in what are termed hospital jars, where the dead eggs and the live ones can be more readily separated. The dead eggs are drawn off every day to prevent them from becoming loaded with silt from the water and sinking into the mass of live ones, from which it is difficult to separate them.

A long-distance siphon is used for removing dead eggs from the jars, saving much labor. In its construction the short end of an ordinary siphon, consisting of a thin ¼-inch brass tube a foot long bent into the form of a gooseneck, is attached to a piece of common rubber tubing 3 or 4 feet long and ⅜ inch in diameter inside. This is connected with a rubber tube of the same size and sufficiently long to reach the entire row of jars in the battery. Hose connections are made by the use of a thin brass nipple of the same interior diameter as the piece of rubber tube to which it is joined. The other end of the long tube is connected to and through the center of a wooden float some 12 inches in diameter and 1 or 2 inches thick by means of a piece of brass tubing. The tube is bent to a quarter circle to prevent the rubber from kinking, and the float is set in a tub. When it is desired to siphon eggs into the jars, a short siphon is placed in the supply trough and started and is then connected with a long siphon. When the tub becomes filled with water, it runs over the rim and into the waste ditch, the eggs settling to the bottom. By means of this siphon an entire battery can be operated without moving the tub. It is necessary, however, to exercise care in siphoning eggs from the jars on the top row, as the suction becomes very strong and is apt to draw off the good eggs. The suction may be reduced by gently pinching the rubber tube.

For convenience and economy of space and water the hatching jars are arranged in tiers, constituting what is known as a *battery*. The structure of a battery, with its system of supply troughs, jars, and other attachments, may be understood by reference to Figures 5 and 31.

The troughs of the battery are usually constructed of white pine or cypress 1½ inches thick. If it is necessary to make the troughs longer than the usual cuts of lumber, the joints should be squarely butted, and these and all other joints in the troughs should be put together with white lead. At the splice a patch is placed on the inside of each trough and screwed to the two ends, white lead being used freely underneath. As a further strengthening measure a cross piece 5 inches high is placed inside. The ends of the troughs are rabbeted in place and the side pieces nailed to the bottom. At the end of each trough in the bottom is a 1½-inch hole, supplied with a plug, for use in cleaning the troughs. At the alternate end of each trough, commencing at the top, is a saw cut 1½ inches deep and 6 inches wide, into which is fitted a galvanized iron or tin overflow spout to conduct surplus water to the next trough below. The lengths of the troughs vary according to the size of the battery. Their inside dimensions are 10½ inches deep and 8 inches wide.

At the proper distance apart along the sides of the troughs are holes for the wooden faucets; for ease in manipulating the jars these holes should be 7¼ inches on centers and 3 inches above the inside bottom of the trough. The best faucets are the Crandell with the tin key. The faucet is connected with the tin tube by a piece of white or red rubber tube 8 or 10 inches long and ½ inch in diameter. The tin tube is ⅝ of an inch in diameter and 20 inches long; three short legs are soldered to the lower end to hold the tube above the bottom of the glass jar.

The troughs are placed one above another at a proper distance to accommodate the type of jar used. They are held together by a support made of 4 by 4 timbers, so placed that a row of 6 jars is installed between each set of stanchions. At the Put in Bay hatchery there are 6 rows of jars, making 36 jars between each set of stanchions. This type uses the stagger system in placing the jars on the battery, by which method each jar of the top row supplies the next jar immediately underneath. The troughs are held together in the stanchions by the use of ½-inch bolts, with nuts and washers at each end, which also act as a support to the trough. Beginning at the top trough the water supply enters one end, supplying each jar on the top row, which in turn discharges into the next trough below. The surplus water passes through the tin overflow at the opposite end and into trough No. 2, which projects from 8 to 10 inches on one end beyond the top trough. This alternate system is continued until the water is finally conducted into the receiving tank located at the end of the battery. This tank is 24 inches deep, 3 feet wide, and of sufficient length to receive the water supply from two batteries. Provision is made at one end of the tank for a screen and an overflow for the diversion of part of the water. The water remaining passes into a series of fry tanks arranged at right angles to the receiving tank, connection between them and the fry tanks being made by means of a 2-inch pipe set 1 foot below the surface of the water and provided with a stopcock. At the Put in Bay hatchery four fry tanks, set in series of two, receive their water supply from the retaining tank. Each fry tank is provided with a screen near its lower end and a similar connection is made between the fry tank and the receiving tank. The fry tanks are 24 inches high, 3 feet wide, and usually 16 feet long.

These screens are made of brass wire cloth, 60 meshes per inch, tacked to a heavy frame. The screen is pulled very tight before it is fastened so as to present a smooth surface to the air jets. The screens should never be painted. The screen frames are held in place by bolts that pass through the frames and into the projecting cleats in the trough. They are not put in place until the fry commence to hatch. If the air pipes are large and are run fairly straight to the screens, an air pressure of from 5 to 8 pounds will be sufficient to keep the screen free from eggshells.

At the Cape Vincent (N. Y.) station a modification of the battery described in the foregoing pages has given excellent satisfaction. (See fig. 31.) It carries six tiers of jars, and where vertical space is available it may be made to accommodate a larger number of jars in proportion to the floor space occupied. The troughs in this battery are made of 1⅜-inch cypress. They are 12½ inches wide, 9¾ inches deep on the feed half, and 6 inches deep on the catch end. The shelves,

which are also made of cypress 1¼ inches thick, are 8½ inches wide, and between the uprights they are supported by steel brackets. The condensation from the jars is drained into the troughs through a groove cut along the outer edges of the shelves. At one end of each trough is a galvanized iron overflow. The supply of water to the batteries is regulated by automatic Ford tank valves, and the discharge, after entering the catch box, is carried to the basement sewer. When the fry are hatching the water is carried, as shown, to the fry building, and under the whole length of the batteries galvanized pans are provided to catch the drip, which drains into the basement sewer. There are 11 jars on each shelf between the uprights, making 198 jars in all on each side of a battery, or 398 jars per battery.

This type of battery is compact and neat in appearance. By means of the grooved shelves and drip pans the floors are kept dry, and, as each trough is provided with a drain plug, they may be scrubbed at any time without interfering with the operation of the jars, the attendant stepping along the jar shelves. At all the bureau's hatcheries it has been found best to use the natural water supply without attempting to modify its temperature, but good results in the incubation of whitefish eggs can not be expected in a water temperature much above 50° F. In early November, when the whitefish spawning season in Lake Erie begins, the water in the Put in Bay hatchery ranges from 40 to 48°. About December 1 it drops to approximately 35 to 38°, and after the lake freezes, or as soon as ice in any appreciable quantity forms, the temperature of the water passing through the jars remains uniform at 32½°. Around the middle of March, when the lake is usually free from ice, the water temperature rises slightly. The fry begin hatching about this time, and as a rule the incubation period is completed in the first week of April.

Every year prior to the opening of the spawning season the interior surfaces of all troughs and tanks are well covered with asphaltum varnish. As a first coating, when the wood is new, white lead and oil are applied, followed by two coats of varnish, the latter consisting of one part turpentine to two parts asphaltum. The best asphaltum pitch is used for filling the cracks and joints, first softening it with paraffin to the consistency of chewing gum, or so that it will not break in cold water. This pitch holds firmly to the wood and keeps its place in warm weather. Other pitches that have been tried are likely to run in warm weather and to harden with use, breaking when cold. All jars, tubes, troughs, etc., should be kept scrupulously clean.

CARE AND PLANTING OF FRY.

When the fry hatch, they immediately leave the jars and follow the course of the running water, those in the upper tiers going through the succeeding jars, and all finally reaching the fry-collecting tank at the bottom, whence they are carried to the main collecting tanks. It has been urged by some that it is injurious for the fry to pass down through the lower jars with the complement of eggs, but in practice this has not been the case.

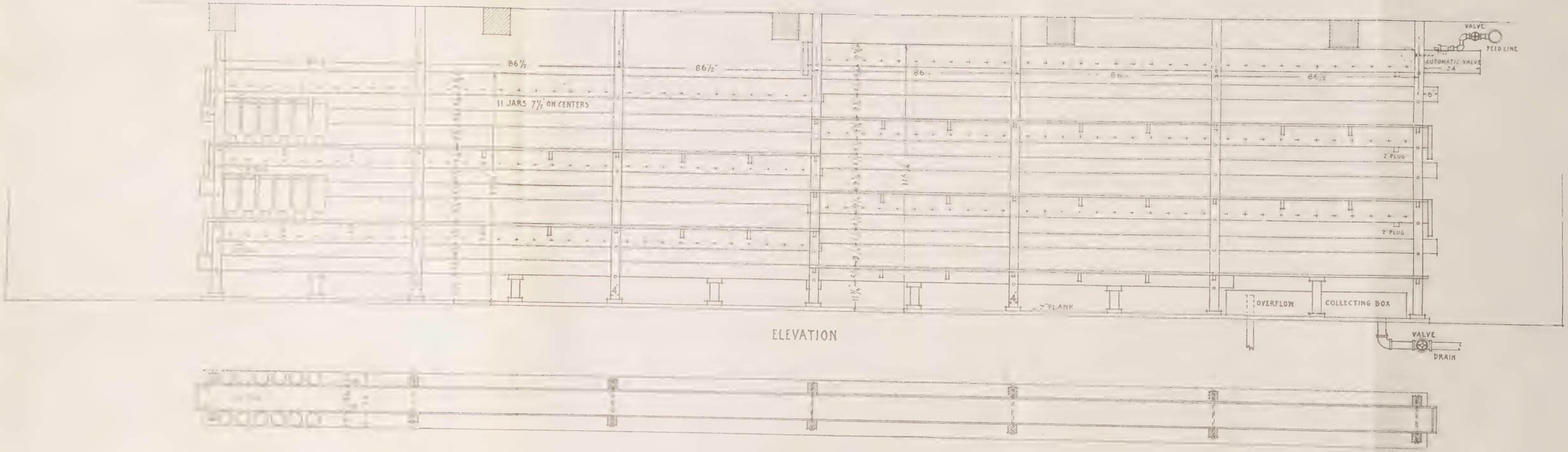


FIG. 31.—Whitefish battery, Cape Vincent, N. Y.

Clogging through an accumulation of eggshells and impurities in the water may be prevented by an air jet, which can easily be arranged for by installing an air pump and carrying the connecting pipe along the side of each tank on the inside of the screen, thence at right angles parallel to the screen and about an inch distant from it. This cross pipe should be perforated on one side with holes one-thirty-second of an inch in diameter and 3 inches apart, the perforations opening toward the screen and upward at an angle of about 45°. When the air is turned on, an apparently solid mass of bubbles will rise along the whole surface of the screen.

With such an arrangement the screen will need no attention for hours, or even days, at a time, whereas without the air jet one or more men must be employed to keep the screens clear. Moreover, many of the fry are unavoidably killed by being forced against the screens and by the work of the men in keeping them free. The thorough aeration of the water indirectly accomplished by use of the air jet is very beneficial when large numbers of fry are passing over, and twice as many can be safely handled in troughs thus equipped.

At Put in Bay, where the fry are planted as soon as hatched, they are dipped from the fry tanks into kegs and transported to the natural spawning grounds on the reefs. From 50,000 to 100,000 fry are carried per keg, according to the distance to be traveled, and when they are to be carried any considerable distance fresh water is added every hour.

Where facilities are available it is advisable to hold the fry in tanks until they have absorbed the yolk sac before planting them, as they are better able at that time to care for themselves than when planted at a very early age. In the spring of 1896 about 1,000 whitefish fry were held in a station trough until late in April, with no food supply except the Entomostraca and other minute life coming into the troughs with the water pumped from the lake. The fish attained a considerable growth and were remarkably active. Cannibalism was of frequent, though not of general occurrence. Toward the close of the period through which they were held numbers were observed to have seized another fry by the tail and swallowed as much of the body as possible; this, of course, being very little. In every instance noted a larger fish had attacked a smaller one, the victim being dead and his destroyer swimming about actively with the body trailing along his side. Had these fry been regularly supplied with food it is probable that no cannibalism whatever would have occurred.

REARING IN PONDS.

Few attempts have been made to raise whitefish in ponds, but the experiments conducted lead to the belief that under favorable conditions the species can, to some extent, be reared in artificial ponds, success along this line, of course, implying an abundance of good cold water and suitable ground for the construction of deep ponds. Such an undertaking would not be practical nor feasible at any of the bureau's hatcheries where millions of fish are liberated.

The outcome of an experiment undertaken in 1882 along this line at the Northville (Mich.) station was successful. Three-year-old

whitefish, from 3 to 4½ pounds in weight, plump and healthy, were produced, and from them a large number of eggs were taken, a fair percentage of which were fertilized. The fish were treated as are young trout, being fed wholly on liver.

Equally successful tests have been made in Europe with one of the native whitefishes (*Coregonus lavaretus*), and noteworthy results have been attained in the rearing of whitefish under private enterprise in ponds at Warren, Ind. It has been found that in rearing the fry the water temperature should not exceed 55° F. and that a temperature of 65° is fatal.

THE GRAYLINGS.

The grayling is one of the most attractive and gamy of the freshwater fishes. Three species have been described from North American waters—*Thymallus signifer* of Alaska and the Mackenzie River region, *T. montanus* of Montana, and *T. ontariensis* of Michigan. They are all closely related to the Salmonidæ in habits and general appearance but differ in the character of the skeleton.

RANGE.

The Arctic grayling (*Thymallus signifer*) is found from the Mackenzie River westward through Alaska and north to the Arctic Ocean. The Montana grayling (*T. montanus*) originally existed only in the streams emptying into the Missouri River above the Great Falls, principally in Smith or Deep River and its tributaries and the three forks of the Missouri—the Jefferson, Madison, and Gallatin Rivers—and their affluents. Its range has since been considerably extended through the agency of fish culture. The Michigan grayling (*Thymallus ontariensis*) was formerly found only in certain streams of Michigan, though the type specimen is said to have come from Lake Ontario. Though once abundant in many streams in the southern peninsula of Michigan, it has now entirely disappeared from the waters of that section. The opinion is expressed by observers that the introduction of the nonindigenous brook trout and rainbow trout has been a factor of importance in their disappearance. Grayling still occur in the Otter River and possibly in other streams in the northern peninsula of Michigan.

DESCRIPTION.

In Montana waters its body is elongated, compressed, the depth contained four and one-half times in the length. The subconic head is of moderate size and its length is one-fifth that of the body. The dorsal outline from snout to tail is a uniform gentle curve, highest at the beginning of the dorsal fin. The mouth is oblique, terminal, and of moderate size; rather feeble teeth, of uniform size, occur on jaws, palatines, and vomer. The short and stiff gill rakers number 17. The eye is large, exceeding length of snout, and is contained three and one-half times in length of head. From 82 to 85 scales are found along the lateral line, 8 rows above and 10 rows below the line. The dorsal fin is long and high and contains 18 to 21 rays; both its length and height equal the depth of body. The caudal is strongly forked. The coloration is gorgeous. The color of the back

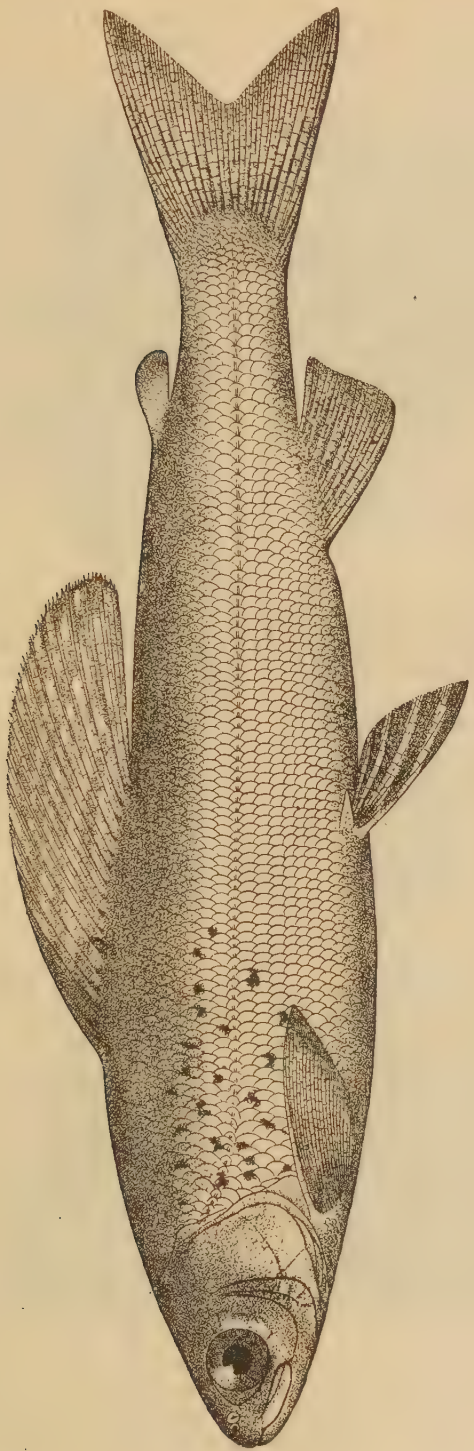


FIG. 32.—Montana grayling, *Thymallus montanus*.

is gray, with purplish reflections; the sides of the head and body are lighter, with purplish and silvery iridescence; the belly is pure white; there are a few V-shaped black spots on the anterior part of the body; a dark heavy line, more distinct in males, extends along upper border of belly from ventral to pectoral fins. The dorsal fin is richly variegated with a rosy border, four to six rows of roundish rosy spots in whitish areas, with dark blotches forming lines between the spots. The ventral fins have three rose-colored branching stripes along the rays. The anal and pectoral fins are plain with dark border.

The Michigan grayling resembles, in general, the fish of Montana, but is distinguishable by its larger dorsal fin and certain differences in coloration. The Arctic grayling has a higher dorsal fin with 22 to 24 rays, a smaller head, contained five and one-half times in length of body, and more brilliant colors; the back and sides are purplish gray, the belly blackish gray with irregular white blotches, and the head brown; on the anterior part of the body are five or six deep blue spots, and on each side of lower jaw a blue mark; the dark gray dorsal has pale blotches and cross rows of rich blue spots edged with red; the ventrals show red and white stripes.

SIZE.

The Michigan grayling rarely exceeds a weight of 1½ pounds, and the average is probably not more than one-half pound. In Montana waters the average weight of *Thymallus montanus* is somewhat greater. As is true with all fish, the size is governed to a considerable extent by the water temperature, food supply, and other local conditions. In Georgetown Lake, Mont., where the Montana Fish and Game Commission has been eminently successful in its efforts to establish the species, the average weight is placed between 1½ and 2 pounds, and although specimens taken in the South Fork of the Madison River weighing as high as 3 pounds have been recorded they seldon exceed 2 pounds in weight.

SPAWNING HABITS.

Grayling prefer clear, cool streams with sandy or gravelly bottom, although they will at times extend their range to streams where the bottom is strewn with bowlders and broken rock. Unlike salmon and trout, it would appear that grayling make no attempt at nest building. In this respect they, perhaps, more closely resemble the whitefish, as they deposit their eggs in the small eddies formed by roots and rocks or on natural barriers of sand and gravel.

In Michigan, where spawning occurs in April, the eggs are normally laid in the gravel beds of clear streams having a temperature range between 50 and 60° F. In certain tributaries of the headwaters of the Madison River, in Montana, they spawn in February and March, while farther down the river, near McAllister and Ennis, the fish spawn late in April or in early May. In Ashley, Ronan, and Rogers Lakes the height of the spawning season occurs late in May and is at least two weeks later in Georgetown Lake.

Grayling usually ascend the tributaries of the larger streams, being very partial to spring-fed creeks for spawning purposes. They are persistent swimmers and whenever possible will ascend

FIG. 33.—Improvised racks are placed across streams to prevent ascent of fish.

FIG. 34.—Taking eggs at a field station.

to headwaters. On numerous occasions they have been observed passing artificial or natural barriers that the native blackspotted and rainbow trouts after repeated attempts have failed to surmount. They prefer streams of a rather sluggish current and containing deep pools, with sandy or gravel bottoms. In Montana streams they usually spawn in a water temperature of 50 to 52° F.

ARTIFICIAL PROPAGATION.

Grayling were first artificially propagated in Michigan in 1874, but the work was never vigorously or regularly prosecuted. It has recently been taken up again by the Michigan fishery authorities. The propagation of this species in Montana was not attempted until 1898, but it has been systematically conducted and has been attended by strikingly good results. It is a noteworthy fact that the species has been successfully established in many waters of the State where it is not indigenous. In this connection Georgetown, Ronan, Rogers, and Ashley Lakes are prominent examples, while more recently it appears that plants of grayling made in waters of the Glacier and Yellowstone National Parks are also yielding material results.

The establishment of the grayling in these and other waters of the State will perhaps serve as a balance against their depleted numbers or entire disappearance in waters where they are indigenous, a condition that has been brought about by the improper methods of fishing formerly permitted and possibly also by the introduction of other nonindigenous fishes.

At the present time artificial propagation of the grayling is practically confined to the work being done by the Montana Fish and Game Commission, and the methods of culture herein described are those pursued and recommended by that commission. The grayling required for the work are captured in a modification of the ordinary upstream trap, formed by placing a rack or barrier across a stream the fish ascend for spawning, and installing, 2 rods or more downstream from that point, another rack containing one or more V-shaped openings. The fish pass through these openings on their upstream journey and are trapped between the racks. Pending the development of the eggs and sperm, it has been found necessary to hold the fish in an inclosure of this kind on a natural bottom, as experience has demonstrated that grayling segregated as to sex or ripeness in wooden pens similar to those used in salmon and trout propagation invariably produce eggs of an inferior quality.

COLLECTION AND INCUBATION OF EGGS.

Unlike practically all other species of fish eggs artificially handled, the eggs of the grayling produce better results when taken by the *wet* method of fertilization, which consists in stripping the eggs into a vessel containing a small amount of water. In the so-called dry method of fertilization the eggs are expressed from the fish into a receptacle that is moist but from which all water has previously been drained. The manner of stripping the males and the females differs in no way from that employed in the propagation of other species of eggs artificially manipulated. A peculiarity of the Montana grayling that has not been mentioned in connection with grayling propaga-

tion elsewhere is the comparatively small amount of milt produced by the males.

When first taken the eggs are of a pale yellow hue and are almost transparent, resembling a drop of honey. They are about one-sixth inch in diameter, nonadhesive, and, because of the presence of a comparatively large oil globule, they are semibuoyant. The average egg production is about 3,000 per pound weight of parent fish. The eye spots, small gilt specks with a minute black pupil, appear in from three to five days, and the eggs hatch in from 12 to 15 days in a water temperature around 50° F.

The eggs may be successfully incubated in the trays or baskets ordinarily used in salmon and trout work, but, because of their buoyant tendency, the Downing jar has been found more satisfactory during the early stages of development. Approximately 125,000 eggs are placed in a hatching jar and held to the eyed stage, at which time it is customary to transfer them to trays for the completion of incubation.

A peculiarity in connection with the development of grayling eggs is the appearance on the green eggs during the first day of an opaque spot, which gradually enlarges until one-half the surface of the egg is covered, giving it somewhat the appearance of a dead egg. This cloudy condition is of short duration and by the end of the third or fourth day is no longer visible. The embryo becomes active in the egg before the eye spot can be seen by the unaided eye.

Eyed grayling eggs can be transported without difficulty when properly packed. Any of the methods in general use may be successfully applied in the preparation of grayling eggs for shipment.

FRY AND THEIR DISTRIBUTION.

The percentage of fry produced from grayling eggs in Montana is low, as a rule, seldom exceeding 50. The young fry are provided with a very small yolk sac. On emerging from the egg they are comparatively helpless and show little signs of animation until the sac is practically absorbed at the end of the first week. They are then free-swimming, about one-half inch long, and quite slender and delicate, resembling the fry of whitefish or shad. At this period they move about in search of food but are never as active as are salmon or trout fry at a similar age.

It is customary to distribute the fry within two or three days after incubation is completed, since the attempts made to rear them have not given good results. The fry do not take readily to artificial feeding, and when moved from hatching troughs to rearing ponds they usually refuse food entirely for the first several days. However, the outcome of recent experiments along this line gives ground for the belief that with proper facilities this difficulty in rearing may be overcome.

THE LAKE OR MACKINAW TROUT.

RANGE.

The lake trout is found throughout the chain of the Great Lakes and the inland lakes of northern New York, New Hampshire, and

FIG. 35.—Lake trout, *Cristivomer namaycush*.

Maine; the headwaters of the Columbia and Fraser Rivers and streams of Vancouver Island; and even waters within the Arctic Circle are said to contain this species. The present paper discusses the trout of the Great Lakes and the methods employed in its artificial propagation at the bureau's stations on Lake Michigan, at Charlevoix, Mich.; on Lake Superior, at Duluth, Minn.; and on Lake Ontario, at Cape Vincent, N. Y.

DESCRIPTION.

This handsome species (*Cristivomer namaycush*), the largest of the trouts, is classed with the charrs. It has an elongated body, the length being about four and one-half times the depth. The head is large, flat above, and about as long as the body is deep. The mouth is large; the maxillary bone extends beyond the eye and is half the length of the head; the jaws have strong teeth. A peculiarity of the vomerine bone distinguishes this fish from the genus Salvelinus; it has a crest provided with teeth extending backward from the shaft of the bone. On the hyoid bone the teeth are in a cardiform band. The eye, placed near the top of the head, is contained only about four and one-half times in length of head. The caudal fin is well marked. Both the dorsal and anal fins contain 9 to 11 rays. In the straight lateral line there are about 200 scales. Branchiostegals 11 to 12.

The coloration is quite variable in fish from different localities. The general color is usually dark gray. The body, head, and fins are covered with small, discrete rounded spots, usually of a pale color but often tinged with reddish. On the back and top of head there are fine vermiculations, as in the brook trout. Examples from some lakes of Maine and eastern Canada are nearly black, and Alaskan examples are often very dark; others are quite pale. This fish is known in Maine and other sections of New England under the name of "togue," and in Canada as the gray trout.

That variety of the lake trout known as the siscowet (*Cristivomer namaycush siscowet*), found only in deep water in Lake Superior, is shorter and paler than the typical fish and has weaker teeth and a shorter head. It is, however, chiefly characterized by an excessive fatness, which greatly reduces its food value.

INFLUENCE OF ENVIRONMENT.

The nature of the environment has a decided influence on the characteristics of the lake trout, the temperature of the water, the food, and the character of the bottom entirely changing the markings and peculiarities of the fish in its various habitats.

FOOD.

Until recently it was commonly thought that the principal food of the lake trout was the young whitefish, and for this reason the fishermen of the lakes were generally unfavorable to its artificial propagation. The error of that belief is now generally conceded, though no doubt quite a number of young whitefish become food for

trout during each season. Inasmuch as the habits of the lake trout take it to deep water immediately after spawning, whereas the young whitefish remain in shallows, the few whitefish that are destroyed in this manner are either stragglers from shoal to deep water or are taken by trout aimlessly wandering from their natural range. The lake trout is an omnivorous feeder and has a ravenous appetite. It greedily devours all fishes possessing fins of flexible character; and jackknives, corncobs, and other articles equally indigestible have been found in its stomach.

ENEMIES.

The spawn and fry of lake trout suffer from the same enemies as the young of all fishes, but the mature fish are too formidable for other species to prey upon. They are troubled with a few parasites. Occasionally individuals very thin in flesh and sickly looking, known to fishermen as "racers," are found swimming near the surface. No sufficient cause has been discovered for this condition, as the racers are no more afflicted with parasites than are healthy fish.

COMMERCIAL VALUE AND ABUNDANCE.

In the early history of the fisheries of the Great Lakes the lake trout was so plentiful that it did not command a price commensurate with its edible qualities. It has since increased in favor and is to-day one of the highly prized and, with the exception of the whitefishes and ciscoes, perhaps the most numerous food fish of the Great Lakes. It is exceeded in weight by the sturgeon only. Instances are cited by fishermen and others of lake trout weighing as high as 125 pounds, and its average weight has been given at from 20 to 30 pounds; but of late examples are rarely found exceeding 10 or 15 pounds. If unmolested by man they might again reach the enormous weight of early citations, their sluggish movements and voracity being conducive to such a result.

In 1917 the catch of lake trout from the five Great Lakes and Lake St. Clair amounted to 13,344,130 pounds, valued at $1,286,704, the catch being exceeded in weight and value only by that of the ciscoes. Very little thought was given to the conservation of the lake trout until 1886, when it became apparent to those interested that decisive steps must be taken to provide against the extermination of a most valuable food fish. Artificial propagation was undertaken at this time and has been continued by the Federal Government and the several States interested. During the fiscal year 1921 the output of lake trout fry and fingerlings from the hatcheries operated by the Bureau of Fisheries amounted to 19,478,500.

Attention was also directed to the desirability of regulating the methods employed in the fishery, and all States have enacted laws specifying the forms of apparatus that may be used and the season of the year when fishing may be legally conducted. Unfortunately such laws are not uniform in their application. However, most of the States require all fishermen to deliver, either to agents of the bureau or the State, all ripe eggs taken in their work or to afford suitable accommodations to spawn takers employed by the bureau or State.

SPAWNING HABITS.

Spawning commences the last of September in Lake Superior and later in the lower lakes, since the water does not become sufficiently cool there as early as in the headwaters. In Lakes Huron and Michigan the height of the season is from November 10 to 20, and spawning continues to the 1st of December. The spawning grounds are on the reefs of "honeycombed" rocks, 10 to 15 miles from shore, and during the reproductive period vast numbers of fish visit these places, spawning in a depth of from 1 to 20 fathoms. Owing to the great depth of water, the shyness of the fish, and the severity of the weather at this time, nothing definite has been determined as to the maneuvers of the fish while spawning. The supposition is that the female lies over an indentation of the rocks and allows her eggs to settle into the "honeycomb" cavities, since fragments of the rock with the cavities filled with eggs have been hauled in by fishermen when lifting their nets. No doubt the general characteristics of the Salmonidæ are carried out by the lake trout so far as is permitted by the conditions in which they exist.

Observers of the spawning habits of the lake trout in Lake George, N. Y., have the following to say on the subject:

> It is the habit of the lake trout to migrate to shallow water for the spawning function, the time varying anywhere from October 25 to November 1, in accordance with the water temperature. During the spawning period fish will be found upon almost every rocky shoal, at the end of an island, or along the main shore line, in from 1 to 4 feet of water, though they sometimes spawn at a much greater depth. Ordinarily spawning occurs in places where there are small bowlders from 1 to 3 feet or more in diameter. Between such bowlders it is possible to see the trout lying side by side in pairs, each heading in an opposite direction, as if to guard against intrusion from all points.

An instance has been known of a Mackinaw trout of 24 pounds weight containing 14,943 eggs; but not over 5,000 or 6,000 eggs are commonly found, and after the trout have attained maturity, at 3 years of age, 1,000 eggs to the pound of fish may be accepted as a general rule.

A much smaller variety, called the shoal trout, is found in Lake Huron in the vicinity of Alpena and in Lake Michigan near Charlevoix and Northport. Its weight compared with its length is greater than that of the true Mackinaw trout. The markings and appearance of the two differ also. The shoal trout spawns in September, about a month earlier than the Mackinaw trout. Its spawning grounds are the cobble, bowlder, or gravel bottoms, in from 2 to 8 feet of water.

ARTIFICIAL PROPAGATION.

COLLECTION AND INCUBATION OF EGGS.

The present methods of fishing for lake trout include gill nets, seines, and pound nets, but most of the eggs taken for artificial propagation are obtained from the gill-net fishermen. The gill nets are operated from steam vessels equipped with the most approved appliances for their trade and with living quarters for a crew of 8 to 10 men.

During the egg-collecting period spawn takers are employed to accompany the fishing boats for the purpose of taking ripe eggs from the fish secured. Where a boat is operating a long string of

FIG. 36.—Tug lifting gill net for lake trout in Lake Michigan.

FIG. 37.—Collecting lake-trout spawn on fishing steamer in Lake Michigan.

nets, or where exceptionally large catches are being made, two spawn takers may be detailed to one boat.

Pans, pails, and dippers are taken on board and made ready by the time the nets are reached. As the net is lifted the men disentangle the trout and throw them on deck, where the spawn takers sort them over, taking the eggs from ripe females and impregnating them with milt from the males. During very severe weather the fish are thrown into the hold instead of on deck, and the work is done there.

On the small gasoline boats operated by two to four men the crew takes the eggs and delivers them to the bureau's agent or to the collecting boat. The eggs are sometimes taken at widely separated points and shipped to the main field station and then to the hatchery.

The manner of taking the eggs is similar to that employed in taking spawn from other trout and salmon. First, a female is taken up and the eggs, if mature, are gently stripped into an ordinary milk pan and then impregnated with milt from a male. This operation is repeated until the pan is half full, when the eggs are "washed up" and poured into a 5-gallon pail. The washing-up process is performed by filling the pans with water and allowing it to run off, repeating the act until the water poured off no longer appears milky. As the specific gravity of the eggs prevents their rising to the surface, this can be done without loss if ordinary care is exercised. The pans are refilled and emptied in this manner until the pail is half or three-fourths full, when it will contain about 75,000 eggs. Other pails or buckets are brought into use as often as may be necessary. To keep the eggs from dying, the water is changed in the large pails every hour until the eggs are taken from the boat and transferred to scrim trays or floating boxes. All pans, pails, and other metallic utensils are coated with asphaltum paint to prevent the appearance of rust, which is fatal to the eggs.

When the weather is so cold that there is any chance of the eggs freezing to the pan, two pans are used. The outside one is partly filled with water, upon which floats the pan that is to receive the eggs as they are stripped. The pan of water protects that part of the inside pan where the eggs rest, and in that way their temperature is kept above the freezing point.

SHIPPING EGGS TO THE HATCHERY.

When spawn takers are operating at a distance, the eggs are held at conveniently located field stations, whence they are sent to the hatchery as soon as possible; but if the stations are at isolated points on the lakes it is often necessary to hold the eggs for several days before means of transportation can be obtained. In such cases the eggs are held in floating boxes, which are made $2\frac{1}{2}$ by $1\frac{1}{2}$ feet by 1 foot, with the ends rounded up about 6 inches. The sides and ends are 1-inch pine and the bottom $\frac{1}{6}$-inch mesh iron wire cloth, which is continued over the rounded ends. Cleats are nailed on the sides, one end somewhat lower than the other, to give the box a tilt when placed in water. Each box carries safely about 180,000 eggs, and when filled it is anchored either in running water or in a sheltered cove of the lake. In the former case a current of water is kept passing through the box, while in the latter the

eggs are given a slight motion by the action of the waves upon the surface of the water.

When eggs held in floating boxes are to be shipped, they are dipped into pails and carried to a place arranged for packing them, where a table upon which to rest the trays has been improvised from any material on hand.

The egg trays are constructed of three-fourths inch material 16 inches square inside measurement, with cheesecloth or linen scrim tacked on one side. A case large enough to contain 19 of these one over the other and to allow for a surrounding air space of 1 inch is made of seven-eighths inch pine. Cleats of one-half inch material are fastened to the bottom, on which the egg trays rest, and 1-inch strips are attached to the inside corners to hold the stack securely in position. The case is provided with hinged cover and suitable handles. Such a case with 18 egg trays, the top tray being

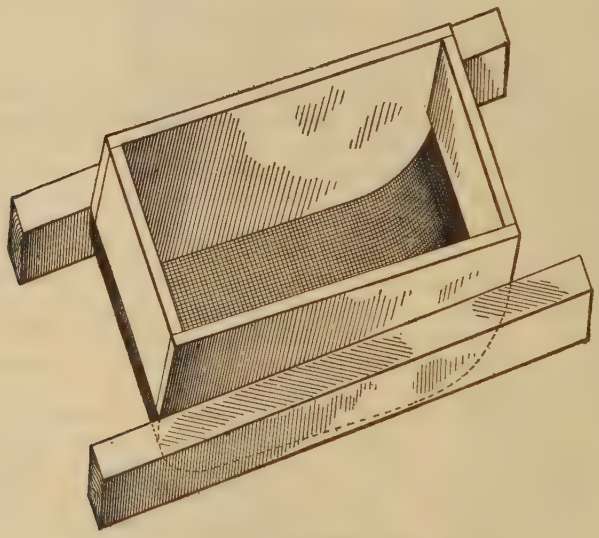


FIG. 38.—Floating box.

filled with moss and serving as a cover for the eggs, has a capacity for approximately 145,000 eggs.

When making up a shipment from a field station, the eggs are transferred from the pails to trays by means of a graduated dipper. About 8,000 are carefully placed on a tray and evenly distributed. This is easily accomplished by a gentle shake of the tray, holding it on a flat, smooth surface. A small amount of water in the measure, added either before or after the eggs are on the tray, will facilitate the work. The use of ice depends upon the outside air temperature and the distance the eggs are to be transported in baggage cars. For short shipments from the field little, if any, is needed. If the case is to pass through a varied air temperature, moss is packed in the space between the trays of eggs and the sides of the shipping case for protection against abrupt changes in the weather.

If it is necessary to hold the eggs on the trays for any length of time, as is often the case, each tray must be taken out and sprinkled

with water at least once every 24 hours. If held for a longer period than four or five days, they must be taken from the trays and washed in a tub of water in the manner described in taking spawn. In adding water the dipper is either held down near the eggs or the water is poured against the side of the tub a little above the surface of the spawn in order to guard against its striking them with such force as to cause injury. Poured in this manner the eggs are given a steady whirling motion and are not injured.

The process of transferring eggs from trays to a tub is very simple. After filling a tub with water to about one-third of its capacity a tray of eggs is placed in the water at an angle of about 45° with its surface, causing most of the eggs to slide down the incline into the tub. The few remaining eggs may be washed down by pouring a little water on the uppermost side of the tray. After giving the eggs a good washing they are replaced on the trays and returned to the cases as described above.

The eggs are shipped in charge of a messenger to insure careful handling at transfer points and when being placed in the baggage car. They must be kept in the coolest place in the baggage car, provided its temperature is not below 28° or 30° F.

MORTALITY OF LAKE-TROUT EGGS.

Because of the difficulties encountered in collecting lake-trout eggs from commercial fishermen for artificial propagation it is not surprising that the percentage of fry produced from such eggs falls below the percentage realized in the hatching of other species of trout whose eggs are obtained under more promising conditions.

In common with the eggs of all the trouts and salmons, the eggs of the lake trout display a strong adhesive tendency when first expressed from the fish. This characteristic persists for a longer or shorter period, apparently depending to a considerable extent on the water temperature. The necessity of absolute quiet during this period has long been recognized in fish-cultural practice. The rolling and pitching of the boats upon which the spawn takers operate prevent the eggs from separating naturally. Separation should occur approximately within 30 minutes after the eggs are stripped, but, as the boats are out from 5 to 24 hours or longer, quiet is no longer of value when they reach the shore. Furthermore, the temperature often falls below the freezing point, and despite all precautions considerable numbers of the eggs are frequently chilled, though the ill effects may not become apparent until after they have reached the hatchery. Other losses often occur through accident or the carelessness of those handling the cases of green eggs while en route to the hatchery.

It is very probable that the greatest loss occurs through improper taking of the eggs. The bureau can not place experienced spawn takers on all the boats, and the fishermen of the smaller outfits take the eggs available and are sometimes careless in performing the operation. Frequently eggs and milt are taken from fish that have been dead for some time. After taking the eggs they are not always cleaned and carefully placed in the kegs. The fishermen are naturally more interested in the catch of fish than in the care of the eggs.

HATCHERY EQUIPMENT.

The hatching trough in use at the Charlevoix (Mich.) station embodies the principles of the Williamson hatching apparatus, with the exception that it has deep pockets and trays (fig. 40). Though simple in construction, this trough possesses more advantages than any other device for the development of large numbers of eggs within a limited space. It permits of a thorough circulation of water; the eggs can be readily handled for picking and cleaning, and the fry may be carried on trays until the yolk sac is absorbed, when they are ready to plant. Only the best 1½-inch pine or cypress is used in its construction, all planks containing imperfections being rejected. The sides and ends are each made of a single piece of lumber, the bottom being made first. All strips of different widths used in the construction are tongued and grooved, and all joints are laid in white lead.

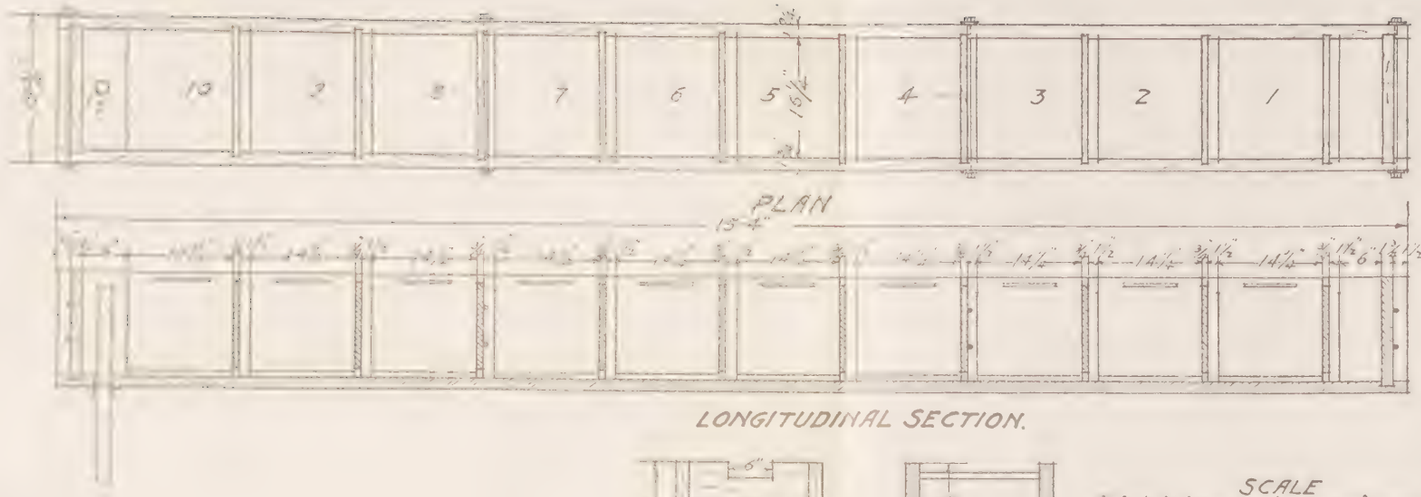
Referring to Figure 40, it will be noted that the trough is divided by cross partitions into compartments 16½ by 14½ inches. The stationary wooden partitions are mortised one-fourth inch in the sides of the trough and are raised three-fourths inch from the trough bottom to allow water to pass under them. They extend to within three-fourths inch of the top. The movable partitions are made of 14 or 16 gauge galvanized iron, set 1½ inches from the others in one-fourth inch saw cuts in the sides and bottom of the trough and are readily removable. These movable partitions extend from the bottom of the trough to the level of the top egg tray.

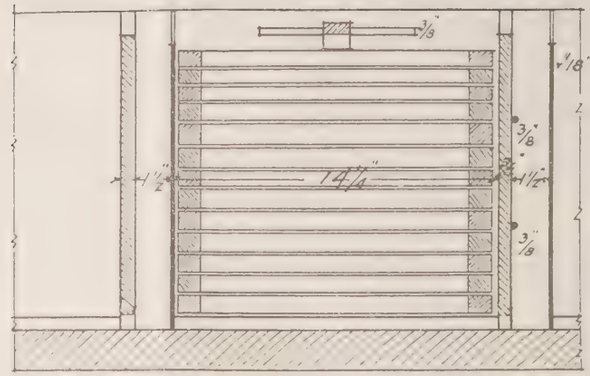
In the bottoms of the compartments thus formed strips one-half inch by seven-eighths inch are nailed at the sides, on which the trays rest. Each compartment holds 13 trays, of which 12 are filled with eggs, the top one serving merely as a cover to prevent the eggs on the twelfth tray from being carried off by the current. About three-fourths inch below the top on either side is a three-eighths-inch groove running the full length of the trough. A cross-bar with a five-eighths-inch block is made to fit into these grooves and hold the trays securely in place, preventing them from rising in the water.

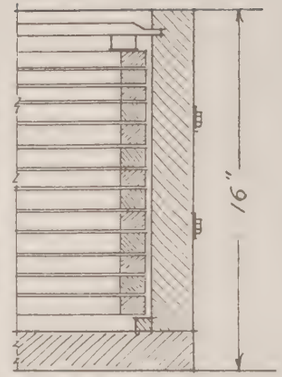
Water enters the head of the trough through a 1-inch pipe, a flow of 5 gallons per minute being the usual volume. By arranging the partition as is indicated in Figure 40, all water must pass from the bottom of the trough upward through each alternate stack of trays containing the eggs or fry, flowing first over an iron partition, under the succeeding wooden one, up through the trays, and so on throughout the length of the trough.

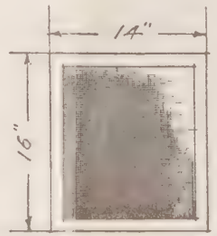
The troughs are set upon iron standards cemented into the floor and are given a pitch of 1 inch to every 8 feet in length. The height from the floor is a matter of convenience to the operator, or it depends upon the fall of water available. The trays are wooden frames 14 by 16 inches, made of seven-eighths-inch strips. They are covered with galvanized wire cloth 14 meshes to the inch for eggs, a smaller mesh being substituted for fry, as is described under care of eggs and fry. The trays will conveniently hold 1 quart of eggs (approximately 6,400) or 3,500 fry to the time they are ready to take food. The troughs and trays are given three coats of asphaltum

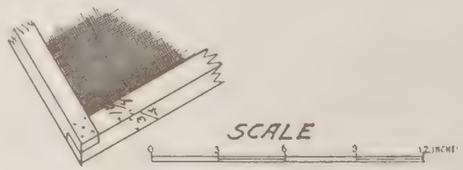
FIG. 39.—Interior of a lake-trout hatchery showing manipulation of eggs.











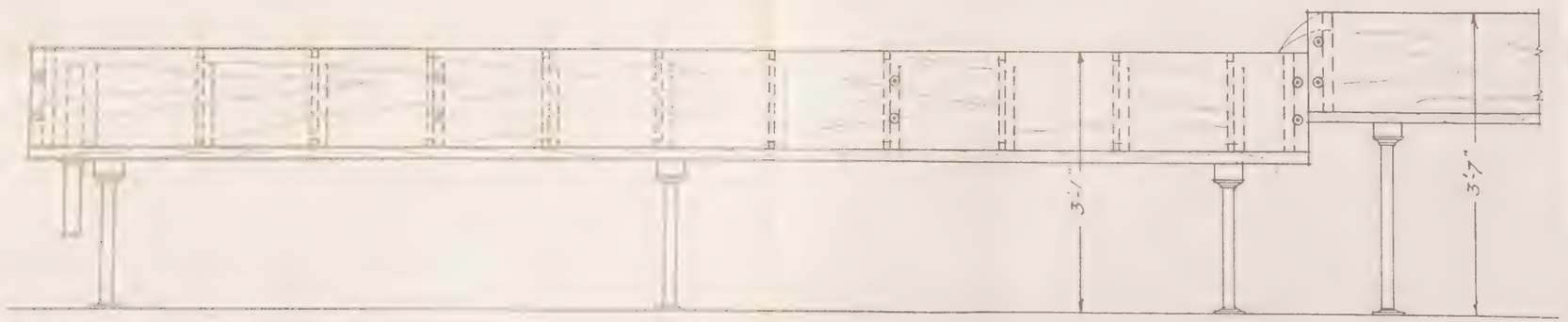


FIG. 40.—Plan of improved Clark-Williamson hatchery tray system.

paint before using and one additional coat at the beginning of each successive season.

Where there is occasion to economize in the use of water, it may pass through two or more troughs, so placed that the overflow from the first trough is 8 inches higher than the head of the one immediately below. This fall gives some aeration to the water, and the results are usually as satisfactory as where an independent water supply is furnished to each trough. In this manner two double troughs, with 38 compartments, occupying a floor space of about 90 square feet, with the required flow of 10 gallons of well-aerated water per minute, will accommodate very nearly 3,000,000 eggs.

If the water supply carries any considerable amount of sediment, or if it is subject to even occasional periods of turbidity from surface drainage or other causes, it is essential to install a filter, otherwise the eggs soon become coated with sediment, the trays clog, and the water circulation is impaired, a condition which is sure to result in serious loss. The bureau has found that water pumped directly from the lakes is the most satisfactory source of hatchery supply. Spring water, with its usually higher temperature, shortens the natural incubation period and for this reason is objectionable.

A convenience in caring for the eggs is a shallow picking trough of any length, 15 inches wide and 2½ inches deep. A strip one-half by seven-eighths inch is nailed along each side of the bottom, and upon these the trays rest, to give a good circulation while the eggs are being assorted. The trough has a fall of not more than one-half inch throughout a length of 20 feet, and it is fed by a flow of about 2 gallons of water per minute. A dam at its lower end raises the water 1¼ inches, not entirely covering the trays. This is a point that must not be overlooked, for if the water flows over the tops of the trays many of the eggs or fry will be washed away.

CARE OF EGGS AND FRY.

On arrival at the hatchery the eggs are removed from the shipping cases and turned into tubs, whence they are transferred to the hatching troughs. In removing them from the shipping trays to tubs the method followed in washing eggs that have been held in cases for several days is employed, the transfer being made at a temperature not exceeding 50° F.

The eggs are measured in a dipper having a perforated bottom, its capacity first being determined by an actual count of eggs, 1 quart—approximately 6,400 eggs—being placed on each tray. A tray is placed in the water and a dipperful of eggs poured upon it and evenly distributed; then another tray, placed on top of the first, is filled, and the operation repeated until 12 trays have been filled. The thirteenth, or cover tray, is left empty and the whole apparatus is secured in place by the use of the cross bar or binder described on page 24. For the first few weeks after the eggs are installed in the hatchery they must be given close attention to prevent the growth and spread of fungus; all dead eggs must be carefully removed and the trays and troughs kept thoroughly clean.

To remove the egg trays for assorting, the binder is first slipped from the grooves and the trays are taken out separately. Each tray will rise to the surface as the one above it is removed, or they may be

taken out as a unit by encircling the stack of trays with a galvanized-iron binder 1½ inches wide. All the trays are taken from one compartment and placed one after the other along the picking trough. The dead eggs, which soon become white and opaque and are easily distinguishable, are then picked out with small metal tweezers. If allowed to remain on the trays, a fungus would soon develop on them and spread its growth until all eggs within a short radius were affected and eventually smothered. When it is necessary to change the position of the eggs, bringing those at the bottom to the surface, it may be accomplished by the use of a soft feather, which, if carefully manipulated, will have no injurious effect. After carefully assorting the eggs the trays are again placed in the hatching trough and are looked over at least every three days during the first five or six weeks.

After the eggs have reached that stage of development where the eye spots are discernible by the unaided eye they are comparatively hardy and less susceptible to injury from handling. At this time it is customary to remove them from the hatching trays and subject them to a thorough washing. This may be accomplished by placing the eggs in pans or buckets and passing a soft feather brush among them; or a stream of water can be introduced into the vessel with sufficient force to agitate the eggs to a considerable extent. This washing not only removes all sediment that may have become attached to the outer covering of the eggs, but it also causes all infertile eggs (ringers), which up to this point have retained the color and appearance of good eggs, to turn white, thus greatly facilitating their removal. If there are only a few infertile or dead eggs, they may be removed by the use of the tweezers mentioned; but if there is a considerable number, their separation can be more readily accomplished by submerging the trays with the eggs in a salt solution. As the specific gravity of dead eggs is slightly less than that of live ones, they rise to the surface of the solution and may be removed with a small net. The salt solution is composed of approximately one part dairy salt to eight or nine parts of water. It is always advisable to test its suitability by introducing into it a small number of both living and dead eggs. Fresh water or salt may be added as required to bring the solution to the proper density.

From this time to the hatching point the eggs will require but little attention, it being necessary to go over them only about once a week for the purpose of removing any accumulation of sediment or an occasional dead egg.

From two to three weeks before the hatching period the eggs are transferred from the trays to tubs of water, carefully washed, and placed on clean trays, after which a careful measurement is made to determine the actual number of eyed eggs remaining in the hatchery. From this time until the fry commence to hatch a careful count is kept of all the dead eggs removed. On the completion of the hatching period this number is deducted from the measurement of the eyed eggs to determine the approximate number of fry. A careful count is also kept of the fry losses up to the time they are ready to plant. In a water temperature of 40° to 45° F. the eye spots are visible in from 20 to 40 days, while the total incubation period is approximately 131 days in a mean temperature of 36°. The fry

absorb the yolk sac in 30 days at a mean temperature of 39°. These stages of development are all subject to considerable variation, being shortened or lengthened as the mean water temperature is decreased or increased. As the time of hatching approaches the distinct outline of the fish is plainly visible in the dark hue of the egg, and the convulsive movements of the embryo fish continue to increase until hatching occurs, when the fish breaks forth from the shell with its tail. The bright warm days of spring and the slightly warmer water temperatures usually bring out 50 per cent of the fry between the hours of 6 and 10 p. m.

Just prior to the hatching period the eggs are removed from the trays on which they have been developing and transferred to trays covered with wire cloth of smaller mesh—16 to the inch. The larger mesh cloth gives a freer circulation of water during the development of the eggs, but the smaller mesh is required for the fry, as the yolk sacs of many of them become enmeshed if a more closely woven cloth is not provided.

Considerable attention is required of the fish-culturist at this time to guard against smothering of the fry. The shells from hatching fish must be removed to prevent clogging of the trays and stoppage of the water circulation. To provide against it, when about 50 per cent of the eggs have completed development, one stack of 12 trays is emptied into a pan of water and the eggs and fry stirred with a feather. This causes the shells to rise to the top, and they can be poured off easily by gently tipping the pan. By repeating the operation several times the hatching fish are entirely freed from refuse. In returning the fish and eggs to the trays they should be divided as equally as possible among the 12 trays. To accomplish this the trays are placed in the picking trough and the fish-culturist starts at the upper end, pouring an equal quantity on each of the trays. Since handling the eggs at this time hastens hatching, it is seldom necessary to give this treatment more than two or three times.

From the hatching period until just prior to the complete absorption of the food sac, at which time the fry are usually distributed, the treatment given them is somewhat similar to that prescribed for the eggs. Monstrosities, "blue-sacs", and dead fry are picked out as soon as discovered. The fry grow very fast at this period; therefore it is not advisable to place more than 3,500 on a hatching tray, 14 by 16 inches in dimensions, which number can be held until they are ready to plant.

DISTRIBUTION OF FRY.

In view of all the considerations involved, perhaps the most satisfactory results are to be obtained from planting lake-trout fry just prior to the complete absorption of the yolk sac. Liberated at this stage of development, they are provided with sufficient nourishment to sustain life until they become somewhat acclimated to their new surroundings and the impulse to forage for their natural food has not been lessened by having artificial food placed conveniently before them. At none of its stations where lake trout are propagated is the bureau equipped for rearing to the fingerling size the large numbers of fry produced. In view of the importance of the industry de-

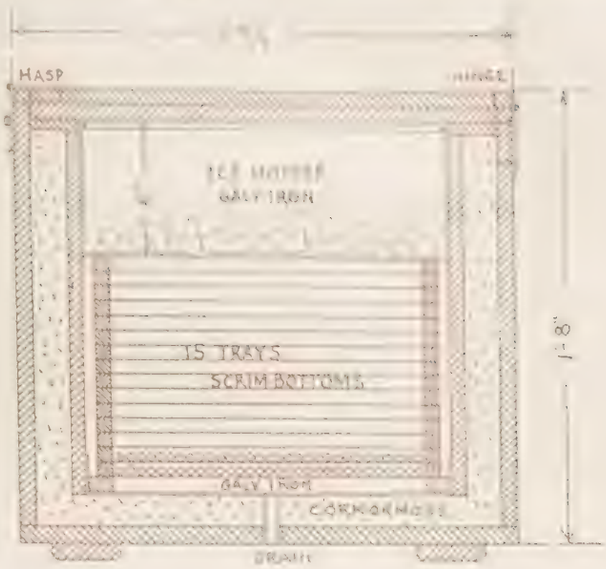
pendent on the lake-trout fishery and the urgent need for exercising the most careful conservation in order to maintain the supply, the bureau has for a number of years found it expedient to distribute the output of its lake-trout hatcheries on the local spawning grounds from which the eggs are obtained. The fry are placed in the ordinary 10-gallon cans used in the distribution work, one tray of fry being carried to each can for medium distances. They are frequently transported in the bureau's distribution cars to a convenient lake port and thence by means of a fishing steamer to the planting areas. However, most of the plants are made by placing the cans of fish on regular commercial vessels employed for the trip. At the Charlevoix (Mich.) station, where the bureau has a boat equipped with two troughs, the trays of fish are carried from the hatchery to the boat, a distance of 100 feet, and placed in troughs, which are supplied with running water by a pump. Since the conditions are the same as in the hatchery, the fry may be carried long distances without loss. Allotments of lake-trout eggs are not infrequently supplied to various State fish commissions, where this course will result in economy in distributing the resulting fry or where possibilities exist for extending the fishery to new and unproductive fields.

PACKING EYED EGGS FOR SHIPMENT.

Just as soon as the eye spots are plainly visible the eggs can be packed and successfully shipped to any part of the United States or to most of the foreign countries, provided they are maintained at a uniform temperature. The shipping trays are usually constructed of material three-fourths inch thick by 1 inch wide, and the bottoms are covered with linen scrim or heavy cheesecloth. The size of the trays depends upon the number of eggs to be shipped. For a 50,000 case of eggs 12 trays 14 inches square are used. After installing the eggs on them the trays are placed one above another in the egg case. The ice hopper is then inserted and the pressure of the lid holds down the entire lot. For shipments to points within the United States where the eggs will not be en route more than four or five days the packing case is insulated with a 1½ or 2 inch thickness of ground cork.

In preparing the shipment the temperature of the room in which the eggs are to be packed should not be higher than 40° or lower than 26° F. The trays are first stacked in order on a table to receive the eggs; then a compartment of eggs that has been previously picked and cleaned is taken from the trough and carried to the packing room in a tub of water. The day before the shipment is to be made up the eggs are usually poured from one pan to another, the slight concussion resulting being sufficient to cause all infertile eggs to turn white. In the packing room most of the water is poured from the tub, and the eggs are removed by the use of a graduated dipper with perforated bottom and placed in a 16-ounce glass graduate. The proper number of ounces is then poured onto each tray, the trays having previously been spread with mosquito bar from 4 to 6 inches wider than their outside dimensions. The eggs are carefully distributed over the surface of the tray, as already described, and the edges of the mosquito bar brought in and lapped

FIG. 41.—Packing eyed eggs for shipment, Northville, Mich.



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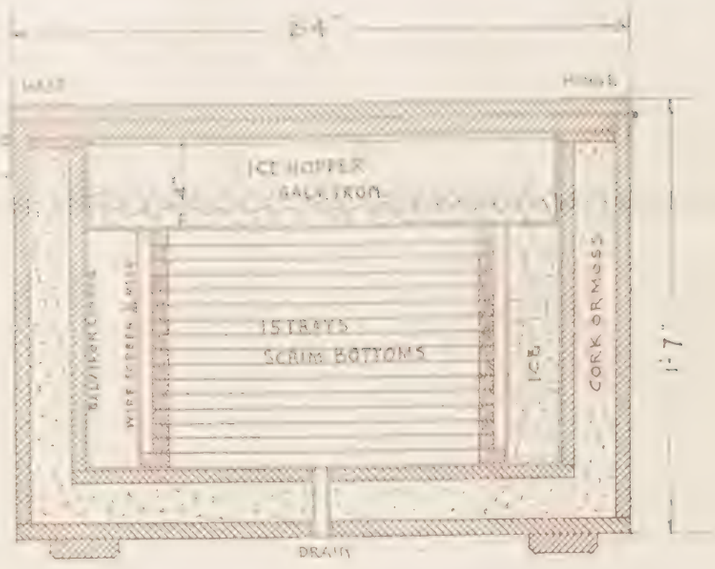

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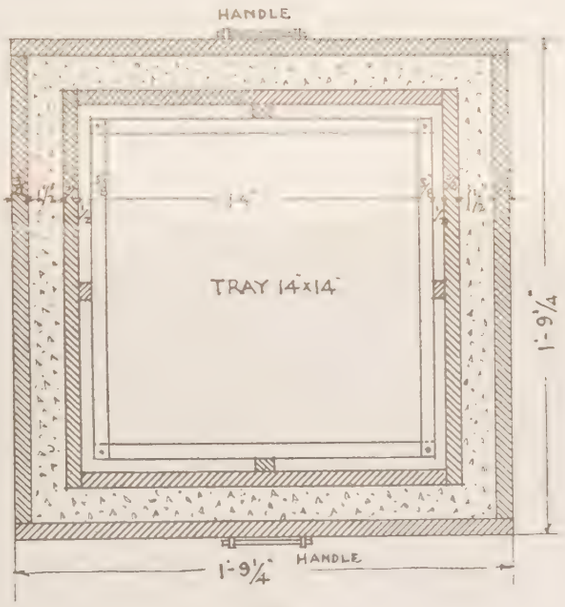

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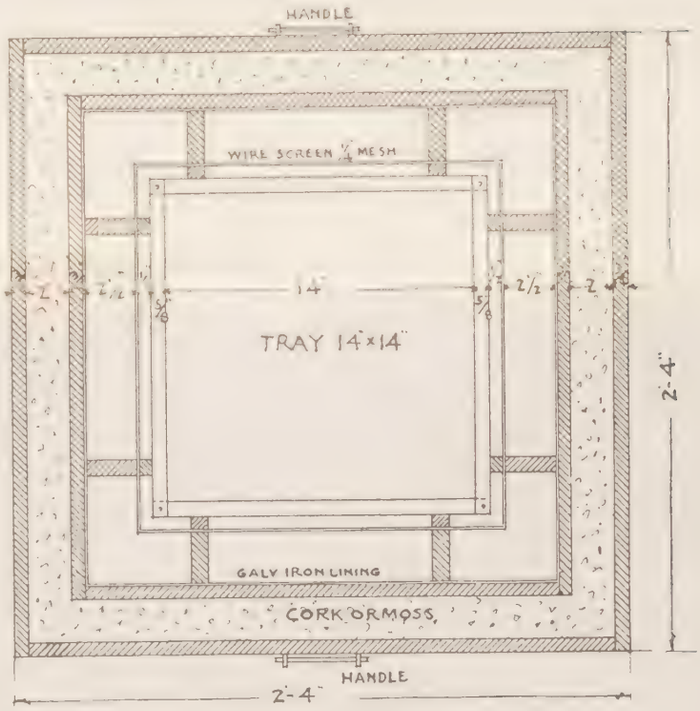

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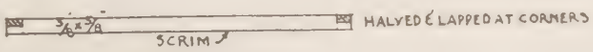
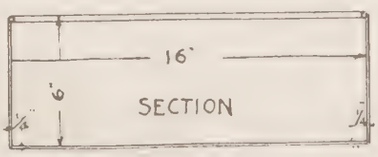
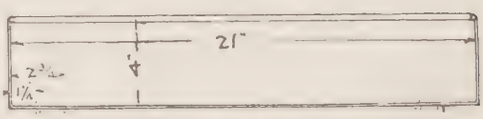
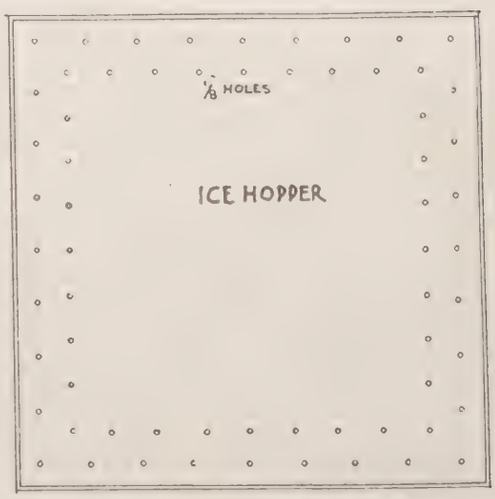


TRAY



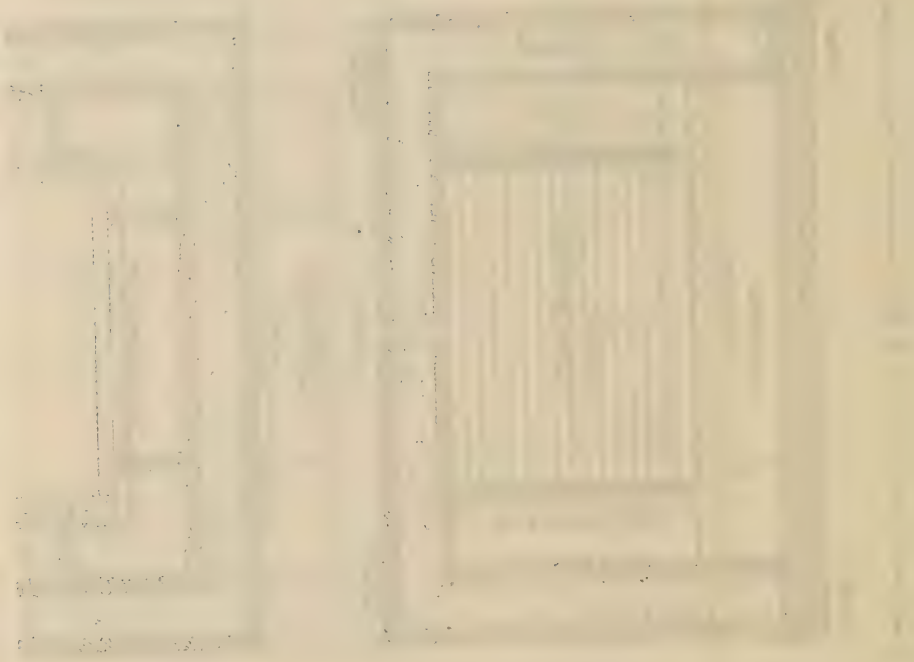


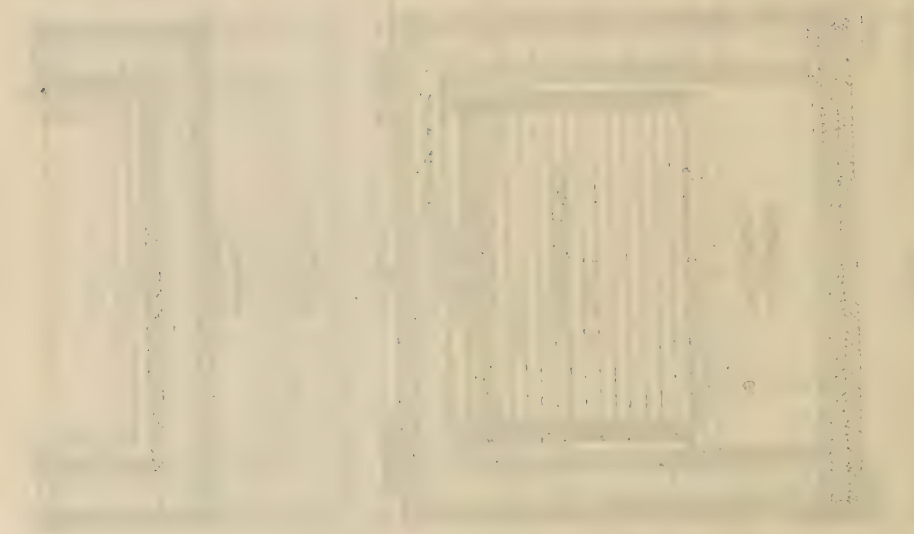


SCALE. 3 IN. = 1 FT.

(32881—23. To face p. 30.)

FIG. 42.—Egg-shipping case.





over the top of the eggs. Unless the shipment is to be in transit a number of days it is not necessary to use moss. When moss is used it is placed between the eggs and the wooden frame of the tray, and frequently some of it is scattered over the top of the eggs, the mosquito bar preventing it from coming in direct contact with them. The best moss for the purpose is known as sphagnum, which is found in low, swampy places. It should be gathered in the fall when green and stored in a damp place until required. It is well soaked in water before placing it on the trays and the surplus water removed by squeezing a bunch of it between the hands.

When packed, the egg trays are placed upon an empty tray that has previously been filled with moss, the upper tray of eggs is covered with a tray of moss, and the ice hopper is put in place. Best results will follow if a block of ice is fitted into the ice hopper. In most of the shipments that are destined to points within the United States crushed ice is not used around the egg trays. Shipments intended for foreign countries are prepared in the same manner, except that moss is placed on each of the egg trays and the outside packing case is provided with a 2-inch thickness of cork insulation. The interior of the case is so arranged as to provide a $1\frac{1}{2}$ or 2 inch space all around the egg trays for crushed ice. An ice hopper is also used at the top. These cases are shown in Figure 42.

FEEDING AND REARING.

Lake-trout fry may be held in troughs and fed, as are the fry of other species of trout. Such a procedure is prohibitive at stations of the Bureau of Fisheries that are concerned with the commercial fishery, owing to the impossibility of providing sufficient space and facilities for accommodating the large numbers produced. Moreover, it is the consensus of opinion among scientists and fish-culturists that better results are assured in this field by planting the young fish on the spawning grounds just before the yolk sac is absorbed, at the time when they are known as "free swimmers." At stations of the bureau where small numbers of lake trout are reared for noncommercial purposes the fish are held in troughs 12 to 16 feet long, 14 inches wide, and 8 inches deep, inside measurement. A screen compartment about 6 inches wide at the head of the trough prevents the fish from coming in direct contact with the inflow of water, and about 1 inch below it is a dam board extending within one-half inch of the bottom of the trough. At intervals of 18 inches throughout the remaining length of the trough cleats $1\frac{3}{4}$ inches high are mortised across the bottom of the trough. In the sides of the trough just above the cleats saw cuts one-fourth inch deep are made for the insertion of screens, their purpose being to distribute the fish evenly in small compartments throughout the length of the trough. After the fish have been fed for two or three weeks they will adjust themselves to the different parts of the trough, when the screens may be removed.

A week or 10 days before the disappearance of the yolk sac the fry intended for rearing should be transferred to troughs. A trough 14 feet long, supplied with 8 to 10 gallons of water per minute, at a temperature ranging from 45 to 50° F., will support 25,000 fry

for two or three weeks after the beginning of the feeding period. As the fingerlings increase in size they must be thinned by removing some of them, and by the time they have attained a length of 3 inches not more than 5,000 can be safely carried to a trough.

For the first four weeks the fry are fed from four to six times a day on finely chopped beef liver or beef heart. The food must be carefully trimmed of all fat and gristle, and, after being run through the finest plate of a meat chopper two or three times, it should finally be passed through a tin having perforations one-tenth inch in diameter. This tin is usually placed between the knives and the plate on the meat grinder. Just before giving it to the fish the food is diluted with water and carefully stirred with a spoon. A small amount is then dipped up with a feather and carefully placed in the troughs. For some days the fish will appear not to be taking their food, but with the continuance of the feeding routine the entire lot will soon commence to feed. No prescribed quantity of food can be suggested for a given number of fish. The amount must depend upon the manner in which the fish take it. From 50 to 70 days after hatching the number of feedings per day may be reduced to three.

The troughs must be thoroughly cleaned twice daily, morning and evening, and during the cleaning process it is usually well to double the flow of water. The foul matter in the trough may be gradually worked to the foot screen with a feather, and by reducing the depth of water in the trough the scurrying of the fish will hasten the flow of sediment toward the foot screen.

After the fish reach a length of 2 or 3 inches they may be distributed in outside rearing ponds. At stations of the bureau where lake trout were formerly reared in ponds from 50,000 to 75,000 fish of this size were held in a pond 100 feet long, 5 to 6 feet wide, and provided with a flow of 35 to 50 gallons of water per minute, at a temperature not exceeding 50° F. Ponds for work of this character should have natural earth sides and gravel bottoms.

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